Integrating urban spatial data using Geographic Information Systems

A case study of Suva

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List of abbreviations

BoS – Bureau of Statistics
CAD – Computer Aided Design
CCMS – Computerised Cadastral Mapping System
DLS – Department of Lands and Surveys
DTCP – Department of Town and Country Planning
ESRI – Environmental systems Research Institute
FEA – Fiji Electricity Authority
FLIC – Fiji Land Information Council
FLIS – Fiji Land Information System
FLISSC – FLIS Support Centre
FMG – Fiji Map Grid
GBF/DIME – Geographic Base File / Dual Independent Map Encoding
GIS – Geographic Information System
ICMS – Integrated Customer Management System
IT – Information technology
ITC – Information Technology and Computing
LIS – Land Information Systems
MGE – Microstation GIS Environment
NLFC – Native Lands and Fisheries Commission
NLTB – Native Lands Trust Board
PWD – Public Works Department
SCC – Suva City Council
SDI – Spatial data Infrastructure
SOPAC – South Pacific Applied Geoscience Commission
TFL – Telecom Fiji Limited
TIGER – Topologically Integrated Geographic Encoding and Reference System
WAN – Wide Area Network
Abstract

Urbanisation is a phenomenon of growing importance globally, and is occurring with increasing rapidity in countries of the Pacific island region. The countries of the region confront a variety of development issues, and are constrained in their management of these issues through a lack of financial and human resources. The management and planning of the rapid growth of urban areas is one such issue, and one reason for the poor management and unplanned growth of urban areas is a lack of accurate, structured and timely data.

Geographic Information Systems (GIS) is a technology that offers a spatial foundation for the collection, storage, management and analysis of spatial data, which can many aspects of urban activity. Over the last 2 decades, GIS has developed into a mainstream branch of information technology, and is now the de-facto environment for the handling of spatial data. In the Pacific, GIS has only recently started to be used. Its relatively recent development, high cost of implementation, and need for specialised skills and training mean that its adoption has been slow and problematic. The institutional environment in which a GIS functions also plays a fundamental role in its success, and this concept is also reviewed.

This study aims to develop the principles for the creation and management of an integrated urban GIS for the city of Suva, the capital of Fiji. A number of GIS are already in operation, working with different aspects of urban data, at a variety of scales. This study suggests that, to be effective, urban data needs to be integrated and made available to all concerned with urban management and planning, in a structured and effective manner. The concept of a Spatial Data Infrastructure (SDI) is proposed as a system to facilitate this integration and dissemination of urban spatial data. The study begins by surveying the current status of GIS in Fiji, with particular reference to GIS activities in the Suva area, and identifies a number of issues, both technical and institutional, that would need to be addressed in order to facilitate the creation of an integrated urban GIS. The next stage was to develop a pilot case study of a sample area, by acquiring spatial data from a variety of organisations, and developing a number of test applications. The experiences gained from the organisational surveys and the pilot case study were used to propose the framework for the implementation of an urban SDI for Suva.
1 Introduction

The process of urbanisation in the Pacific is complex and integral to the development of the countries of the region. Globalisation is turning the spotlight of economic development on towns, cities and urban areas. In the Pacific, urban areas are growing considerably faster than the average population growth rate, putting increasing pressure on urban resources (UNDP 1996). Outside urban areas, fringe settlements are springing up, often uncontrolled and unregulated, resulting in sprawling peri-urban hinterlands. Appropriate and effective urban management and land use planning are imperative if urban areas are to achieve any degree of sustainability. An integral part of this management and planning process is the effective utilisation of appropriate tools and technologies. One such group of tools are geo-spatial technologies, of which Geographic Information Systems (GIS) occupy a central position.

1.1 Overview of study

This study is concerned with linking some of the problems of urbanisation with some of the geo-spatial tools that could be used to assist in the management of these problems and in planning responses to them. Many of the problems and issues of rapid urbanisation are recognised and documented, but what is lacking, especially in the Pacific region, are clearly defined strategies for dealing with these problems (Connell and Lea 1993). The reasons for this lack of clear strategy are many and varied, and one of them is the problem of data management. While there is much collection and analysis of data concerning urban areas, it is often carried out in isolation from other data collection and analysis operations. Various government departments, municipal authorities, statutory bodies and commercial organisations collect and analyse data as it pertains to their individual operations. The complexity of urban areas, and the inter-related nature of many of the problems of urban managing and planning, mean that any kind of management and response planning needs to integrate as much data as possible, from as wide a spectrum of urban activity as possible. This study will examine the issues involved in building a framework for the integrating of urban spatial data, using geo-spatial tools and technologies.

GIS has a relatively long history of applications in urban management and planning. In the developed world, it is an almost ubiquitous part of this process. The recognition that much of the data about urban areas and urban processes is geographically referenced provides a spatial framework for assimilating and analysing data from a variety of sources. Geo-spatial
technologies, primarily GIS, provide a digital environment for this process to take place. Due to their cost and complexity, geo-spatial technologies have only recently begun to be adopted in developing countries. In the Pacific, this has largely been in the form of the computerisation (using GIS) of some of the operations of national mapping agencies. While this has provided a digital base of topographic (and in some cases cadastral) data, the use of integrated spatial data in the urban environment has yet to become common practice.

While many of the challenges for creating integrated data sets of urban environments (using geographic frameworks and geo-spatial technologies) are technical, there is a growing recognition of the importance of the institutional and social aspects of using geo-spatial technologies (Campbell and Masser 1995). The process of implementing a GIS is rarely a case of acquiring a black-box system. It requires an extensive, and sometimes radical, review of the organisation's workflow, re-training of staff, and significant expenditure of resources, if it is to be effective. The implications of such changes can dramatically affect the nature of power and influence within an organisation, putting the aspect of GIS implementation in a social and cultural perspective. Similarly, GIS rarely exist on their own, often requiring collaboration (such as data sharing) with external sources and other organisations. The dynamics of the exchange of data can have serious implications for any kind of integrated system, and is therefore a fundamental consideration for any kind of urban GIS application, which requires a variety of disparate data to be truly effective.

The processes and problems of urbanisation have been extensively documented at a variety of global, regional and local scales. Similarly, the use of geo-spatial technologies for various aspects of urban planning and management has been extensively described from a variety of technical and institutional viewpoints. What is of growing interest in the GIS community is the use of geo-spatial data and tools to integrate a variety of data sources to address, in a more holistic approach, some of the more complex problems of urban management and planning. This study takes this approach by attempting to develop a framework for integrating various geo-spatial data sets, and using these integrated data sets, together with GIS tools and techniques, to enhance some aspects of urban spatial data use. To do this, a specific geographic area has been chosen, which will form a case study to assist in the development of this framework.
1.2 Problem statement

The efficient use of geo-spatial tools to enhance urban planning and management operations require coordinated and integrated data sets. The main problem with creating and working with these integrated data sets is that much of the data collected in (and about) urban areas is carried out by agencies and organisations working to achieve separate and sometimes independent objectives. While this may satisfy the individual data needs of these organisations, a more holistic approach to urban management and planning can be achieved by integrating these data sets.

The Greater Suva area is an example both of rapid urbanisation in the Pacific, and of the data collection and management issues described previously. In common with other urban areas, various agencies and organisations collect and process data about the urban environment. While much of this data exits in relative isolation within these various agencies and organisations, geo-spatial tools can be used to merge them to create integrated data sets, and provide a more holistic view of the urban environment. Before this can be achieved, various institutional and technical issues need to be addressed. The institutional issues are centred around the nature and role of GIS within the organisation. The technical issues are centred on the form and structure of the data, and how the data is used within the organisation.

The problem this study attempts to address is to enable the integration of urban spatial data for the Greater Suva area. The disparate nature of much of the existing data sets and data collection methods mean that while much of the data is, or can be, geographically reference, this has not happened. What is lacking is a comprehensive documentation of this data, and a procedural framework describing how the data can be integrated. Because much of the spatial data collected and used by organisations involved in urban planning and management is used almost exclusively within the organisation, the nature and structure of the data is often known only to those working with it on a daily basis. To potential users of this data from outside the organisation, the data may appear to be unsuitable for a particular task because of the lack of documentation about the data.

1.3 Aims and objectives

The primary aim of this study is to develop the principles for the creation and management of an integrated urban GIS for the city of Suva. While much potentially useful geographic data
exists in a variety of organisations, structures and formats, there is little activity taking place towards the integration of this data. This study will examine the reasons behind this lack of integration, and will attempt to build a technical and institutional framework that will allow for the more effective integration of this data.

This study will attempt to meet this aim by examining both the technical and institutional environments in which data, in particularly spatial data is used and managed. From a technical perspective, the way in which spatial data is collected and managed in various organisations will be documented and analysed. This will be then be set in the context of the structure of the workflows within the organisation (and between organisations, where appropriate) to identify issues relating to how data is used and how it could be used.

Following this review, a sample integrated data set will be created using data from various organisations. This sample data set will be used to demonstrate the capabilities of the use of existing data, and discuss the possibilities for enhancing and expanding on these uses. From this sample data set and subsequent analysis, a structure will be suggested that could be used to realise some of the possibilities of urban management and planning using integrated spatial data and geo-spatial tools.

1.4 Research approach

The research approach for this study will use a combination of techniques. For the evaluation of the GIS within the various organisations, a series of structured questionnaires were used to establish baseline information about the role of GIS in the organisation, and how data is collected and managed. Once this baseline has been established, in-depth interviews were carried out to evaluate the success and perceptions of the GIS within the organisation. From these assessments, conclusions were drawn about the efficiency of the GIS, and how well it might participate in an integrated system.

Following this organisational assessment, sample data sets from the various organisations were obtained, documented and integrated. This process enabled a better understanding of the technical issues facing the creation of a framework for an integrated system. From this data, a number of sample applications of GIS for integrated urban management and planning were generated. These sample applications were then used to study the technical limitations
of the data and to document what steps need to be taken to adjust the existing data and data collection methods for more efficient integration.

Finally, using this assessment of the institutions and the data, a structure was proposed based on the emerging concept of Spatial Data Infrastructures (SDI). This structure will consist of a set of guidelines and policy proposals that could be used by the various organisations to make their data and operations more easily integrated for the purpose of more efficient urban management and planning.

1.5 The study area

The area chosen for this study is the Greater Suva area. The reasons for this are because of its rapidly urbanising characteristic, the high density of data, the author’s knowledge of the area, and the number of organisations and agencies collecting and working with spatial data. All of these factors combine to create an environment that provides a useful case study for the objectives outlined above.

The greater Suva area is one of the largest, continuous urban agglomerations in the Pacific region. It covers an area of approximately 75 square kilometres, and falls under the administrative responsibility of four municipal jurisdictions and a number of rural authorities and statutory organisations. The city of Suva is the headquarters for a number of government departments, including the Department of Lands and Surveys, which is responsible for mapping and surveying at the national level. A number of other relevant government departments (such as the Department of Town and Country Planning, Public Works Department and the Bureau of Statistics), the Suva City Council (the municipal authority for the city), statutory organisations (such as the Native Lands Trust Board) and private companies (such as Telecom Fiji) all work with spatial data and have their headquarters and GIS operations in the city. The activities and goals of these different organisations vary widely, but all have a common interest in the spatial location and distribution of infrastructure and activities. Each of these organisations collects and incorporates spatial data in various aspects of their operations, creating a data-rich environment, but lacking in integration and cooperative data exchange.
1.6 Organisation of thesis

This thesis is divided into six chapters. This chapter has given a brief overview of the potential for the use of spatial data and geo-spatial tools to enhance the process of urban management and planning. The use of these data and tools is dependant on various technical and institutional issues, which will be explored and expanded upon.

Chapter 2 contains a review of the literature with reference to four main areas. Firstly, an overview of urbanisation in the Greater Suva area is presented, outlining some of the issues caused by rapid urban expansion. Secondly, the main uses of geo-spatial technologies for urban management and planning are summarised under the topics of land information management, visualisation and simulation providing an overview of the data and technology environment. Thirdly, the issues involved in the implementation of geo-spatial technologies are reviewed, with emphasis on implementations across different organisations. This provides a background for the institutional environment for integrated urban management and planning. The fourth and final section of the literature review deals with the concept of SDI, and how SDI can be used to facilitate and enhance the process of integrating data for more efficient urban and management planning.

Chapter 3 reviews the methodology taken for the study. In particular, it reviews the recent emergence of qualitative research in information technology (IT) in general, and GIS in particular, and summarises some of the main trends. While much of the research in GIS is still data and technology oriented, there is a growing body of work that relates the data and technology to the institutional environments in which GIS exist. Studying these relationships require a variety of qualitative and quantitative methodologies.

Chapter 4 contains the results of the study in two main sections. The first section presents the results of the questionnaire surveys and detailed interviews, and outlines the role and nature of GIS within the organisations surveyed. The second section presents the result of the data integration study, in the form of a documented and integrated data set and a series of sample applications using the data set.

Chapter 5 discusses the results of the organisation survey and the data integration study, in the context of integrated urban management and planning. The main issues of spatial data
integration and organisational workflow alignment will be discussed with the aim of proposing a framework for a SDI for integrated urban management and planning for the Greater Suva area.

Chapter 6 presents conclusions about integrated GIS in the context of spatial data and organisational structures and workflows, based on the results of the study. It concludes with a series of recommendations that could enhance the processes of integrating urban spatial data and suggestions for future research.
2 Literature review

This chapter presents a review of the literature relevant to the study under four main topics. Firstly, the process of urbanisation is reviewed, focusing on the major trends and issues of urbanisation in the Pacific region. Secondly, the application of GIS in the urban environment is presented, noting the main data and institutional structures that have produced useful GIS applications. Thirdly, the social and institutional context in which GIS (and other technologies) function is acknowledged and reviewed from the perspective of the process of diffusion and implementation of GIS. Finally, the concept of SDI is reviewed, with a view towards developing an SDI-based system of data distribution for urban applications of GIS in the context of the study area, in this case greater Suva.

2.1 The urban trend

The rate and process of urbanisation is an important aspect of many of the development, environmental, planning and management issues in developing countries. The countries of the Pacific are no exception, and in some places are experiencing urban growth and density among the highest in the world. The management and planning of this process is often cited as a necessary part of economic development, environmental protection and poverty alleviation. GIS and related geo-spatial technologies are one of a number of management tools that have been recommended to help in the process of urban management.

This section will review the process of urbanisation in the context of the Pacific island region in general, and Fiji in particular. This will then be followed by three sections, looking at various aspects of GIS and geo-spatial technologies, and how they relate to urban management and planning. The various uses of GIS in urban management will be reviewed, followed by the issues involved in the diffusion and implementation of GIS, and ending with a review of the concept of SDI.

2.1.1 Defining urban and urbanisation

The concepts of urban and urbanisation have been the focus of various branches of geographical study since geography became a recognised discipline in its own right. A wide variety of perspectives on urbanisation have been studied. While there are many definitions of urbanisation and of what constitutes urban spaces and urban processes, a number of
common themes can be identified in relation to the study of urban geography (Herbet and Thomas 1982).

The first and most visible aspect of the concept of urbanisation is population. Urban areas are often defined in terms of relative population sizes and densities. While the definitions of urban areas based on population statistics are highly variable, the use of population and demographic data has been a source of much of the research carried out by urban geographers.

A second approach considers the urban concept with respect to the functions of an urban area. These include the absence of agricultural activity as the basis of the economy, which is centred on exchange rather than production. Administrative and cultural functions can also be used to define an urban area, and these are usually based on some historical aspect of the area. Towns and cities that have their roots around places of worship, fortified defences, or seats of legislation and administration are examples of these. In many cases, the historical root of the urban area has long since disappeared, superseded by the economic activities that have sustained the area.

A third aspect is the concept of urbanism, usually defined in terms of people's behavioural patterns, which has given a sociological and psychological perspective to the nature and processes of urban areas. The research suggests differing sets of values between urban and rural populations, which influence and are influenced by the urban landscape.

These three approaches to defining the urban concept are all contentious and lacking in any kind of generally accepted consensus. Rather, they are considered useful perspectives for inquiry into aspects of urban place, space and processes. In partial response to this, the emphasis in terms of urban definitions has shifted to defining 'urban place' as an entity. This has a markedly spatial perspective, in that it attempts to define functional spatial units of urban regions, and to develop a framework to standardise these units for comparative analysis.

It is this approach which has increased the opportunity for urban geography to interact with GIS. The concept of a spatial object in GIS can be linked to the concept of defining spatial units of urban areas. While the actual form and function of these urban units are largely
relative, GIS provides a framework of the capture, storage, management and analysis of these units, thus providing some level of standardisation at the data aggregation level.

The classical models of urban form and function, such as Burgess' concentric zone model, Hoyt's sector model, and Harris and Ulman's multiple nuclei model provide the foundation for contemporary urban morphology. During the quantitative revolution of the 1960s, many variations and refinements of the basic models were made, assisted largely by the increased computing power available, and early computer mapping and spatial statistics software. The quantitative focus of these studies, and their lack of ability to directly affect or interpret the human aspects of urban change have led to a more holistic approach to urban geography, in which spatial and statistical patterns of urban change are increasingly being interpreted in terms of the processes which influence them, and from which appropriate responses can be developed.

2.1.2 Urbanisation in the Pacific region

The last 50 years have seen a remarkable growth in urban populations in the countries and territories of the Pacific region. While the region has traditionally based its economies and societies on rural subsistence and plantation agriculture, there has been a fundamental shift towards a more urban character. While the rural and subsistence aspect of societies still remains a vital part of the region, they can no longer be considered to be the defining characteristic. The role of urban places and the process of urbanisation are becoming increasingly important in defining and analysing a wide variety of social, economic, political and spatial processes. The populations of the countries of the region are becoming increasingly urbanised, and this change is taking place relatively rapidly in some places, with urban growth rates exceeding rural and national growth rates.

The form of urban spaces and the process of urbanisation in the Pacific region have some unique characteristics that contribute to the difficulty of defining exactly what constitutes urban space and the process of urbanisation. The first of these is the small size of many of the islands and countries in the region, which makes the measurement of movement from rural to urban extremely difficult. The spatial extent of these movements are extremely small, making studies of spatial patterns and processes more difficult. This is especially true in the atoll islands, where the spatial extent of urban growth can only occur along the axis of the atoll, gradually subsuming villages and previously rural settlements, as the urban space
spreads. Majuro and south Tarawa are good examples of this phenomenon, where a relatively small increase in urban area translates into a relatively large distance of movement of the urban boundary. In the urban areas of the larger islands of the regions, previously rural villages have also been subsumed by the rapid growth of the urban areas. The urban villages of greater Suva, Apia and Port Moresby introduce an added dimension to any analysis of urbanisation in these areas (Connell and Lea 1993).

Table 2-1. Selected demographic data showing urbanisation trends of Pacific island countries and territories.

<table>
<thead>
<tr>
<th>Region/country or territory</th>
<th>Last census</th>
<th>Population as counted at last census</th>
<th>Population density (people/km²) 2000</th>
<th>Projected annual population growth rate (%) 2000</th>
<th>Urban population (%)</th>
<th>Annual intercensal urban growth rate (%)</th>
<th>Annual intercensal rural growth rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MELANESIA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiji Islands</td>
<td>1996</td>
<td>775,077</td>
<td>12</td>
<td>2.3</td>
<td>21</td>
<td>3.6</td>
<td>1.9</td>
</tr>
<tr>
<td>New-Caledonia</td>
<td>1996</td>
<td>196,836</td>
<td>45</td>
<td>1.6</td>
<td>46</td>
<td>2.6</td>
<td>-0.5</td>
</tr>
<tr>
<td>Papua-New-Guinea</td>
<td>1990</td>
<td>3,607,954</td>
<td>10</td>
<td>2.3</td>
<td>15</td>
<td>4.1</td>
<td>2</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>1986</td>
<td>285,176</td>
<td>16</td>
<td>3.4</td>
<td>13</td>
<td>6.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>1999</td>
<td>193,219</td>
<td>16</td>
<td>3.0</td>
<td>21</td>
<td>4.3</td>
<td>2.5</td>
</tr>
<tr>
<td>MELANESIA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federated States of Micronesia</td>
<td>1994</td>
<td>105,506</td>
<td>168</td>
<td>1.9</td>
<td>27</td>
<td>0.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Guam</td>
<td>1990</td>
<td>133,152</td>
<td>274</td>
<td>1</td>
<td>38</td>
<td>1.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Kiribati</td>
<td>1995</td>
<td>77,658</td>
<td>112</td>
<td>2.5</td>
<td>37</td>
<td>2.2</td>
<td>1</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>1999</td>
<td>50,840</td>
<td>286</td>
<td>2</td>
<td>65</td>
<td>1.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Nauru</td>
<td>1992</td>
<td>9,919</td>
<td>545</td>
<td>1.8</td>
<td>100</td>
<td>1.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Northern Mariana</td>
<td>1995</td>
<td>58,846</td>
<td>163</td>
<td>5.5</td>
<td>90</td>
<td>5.6</td>
<td>5.9</td>
</tr>
<tr>
<td>Palau</td>
<td>1995</td>
<td>17,225</td>
<td>39</td>
<td>2.2</td>
<td>71</td>
<td>2.9</td>
<td>1.2</td>
</tr>
<tr>
<td>POLYNESIA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Samoa</td>
<td>1990</td>
<td>46,773</td>
<td>321</td>
<td>2.9</td>
<td>48</td>
<td>4.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Cook Islands</td>
<td>1996</td>
<td>19,103</td>
<td>79</td>
<td>-0.5</td>
<td>59</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>French Polynesia</td>
<td>1996</td>
<td>219,521</td>
<td>66</td>
<td>1.6</td>
<td>53</td>
<td>1.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Niue</td>
<td>1997</td>
<td>2,088</td>
<td>7</td>
<td>-3.1</td>
<td>35</td>
<td>1.2</td>
<td>-2.4</td>
</tr>
<tr>
<td>Pitcair Islands</td>
<td>1999</td>
<td>47</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Samoa</td>
<td>1991</td>
<td>161,298</td>
<td>58</td>
<td>0.6</td>
<td>21</td>
<td>1.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Tokelau</td>
<td>1996</td>
<td>1,507</td>
<td>125</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Tonga</td>
<td>1996</td>
<td>97,784</td>
<td>154</td>
<td>0.6</td>
<td>32</td>
<td>0.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Tuvalu</td>
<td>1991</td>
<td>9,043</td>
<td>381</td>
<td>0.9</td>
<td>42</td>
<td>4.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Wallis and Futuna</td>
<td>1996</td>
<td>14,166</td>
<td>57</td>
<td>0.7</td>
<td>0</td>
<td>0.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Source: (SPC 2002)

A further aspect that contributes significantly to the complexity of defining urban spaces and urbanisation is that of land tenure. There are a variety of land tenure systems in the region.

1 Federated States of Micronesia
characterised by a mixture of privately owned, state owned and traditionally owned land (Bryant 1993; Connell and Lea 1993). Most urban centres in the region have their historical roots in land that was either privately owned, or state controlled. Over time, the original boundaries of these urban settlements have been exceeded, and urban activities are increasingly taking place on traditionally owned land. The process of utilising traditionally owned land is contentious, and beyond the scope of this study to discuss in any depth, suffice as to say that it has further complicated the definition of urban space and the process of urbanisation (Connell and Lea 1995).

The separation between rural and urban is also complicated by the lack of land use control in many parts of the region. A process of ruralisation of urban areas is taking place, characterised by the weakening of land use controls resulting in the diverse utilisation of urban space, the spread of informal settlements such as squatter settlements and traditional villages, the deterioration of urban services and infrastructure, the rise of informal economic activities, the maintenance of rural economic links, and the importance of urban agriculture (Hardoy and Satterthwaite 1989). In many parts of the region, urban dwellers, especially those in the low income sector, supplement their income and diets through small-scale agriculture and fisheries. Urban food gardens and coastal fishing give a rural characteristic to many urban areas, providing a vital food and supplementary income source to those living on the periphery of the larger urban areas. These factors, combined with the relative mobility of the population, leads to a situation where deciding who is urban, and how permanent their urban or rural status is, can be highly problematic (Bryant-Tokalau 1995).

The extent of urbanisation in the Pacific region has become great enough such that most of the driving forces reshaping the economies, societies, politics and geographies of the region have their origin in urban areas (Ward 1998). Some of the features of this process include (Connell and Lea 1998):

- economic development increasingly emphasising urban issues, with new developments (particularly increasing industrialisation) putting pressure on the urban infrastructure
- land use plans and provisions for urban management tend to be lacking or are not implemented
• issues affecting urban development are pursued in several different administrative and operational departments (among which there are often conflicts and uncertainties over the division of responsibility)
• piecemeal development and lack of long term urban development plans
• an often substantial proportion of the infrastructure, in particular water and sewerage, was constructed during colonial times and for towns and populations much smaller than the present size
• standards that proved adequate in the past are less likely to be adequate in the future as expectations rise and urban residence becomes more common
• costs of providing services are high

These features of the urbanisation process in the Pacific have resulted in often uncontrolled and poorly managed urban areas. Urban services and infrastructure struggle to deal with problems within municipal boundaries, while outside these boundaries, large fringe and peri-urban settlements are continually growing. Urban areas in Fiji are typical of this, with the Greater Suva area providing many examples of these processes and issues.

2.1.3 Urbanisation in Fiji

Fiji is fast becoming one the most urbanised countries in the Pacific region. The percentage of the population living in urban areas has seen a rapid increase as a result of natural population growth, rural to urban migration, and the spatial growth of urban areas (Connell and Lea 1993). While agricultural and mineral products and tourism continue to dominate the economy, there is a significant and growing contribution from manufacturing and industrial activities, which has contributed to the growth of urban areas, urban populations and urban activities. With the rapid rate of urbanisation, one of the major issues in studying the phenomena has been in defining and measuring this process. This section will briefly review the theoretical concepts of urbanisation, followed by a review of this process in Fiji focusing on the greater Suva area.

Fiji is experiencing a relatively complex process of urbanisation and has one of the longest histories of urbanisation in the Pacific, beginning with the first capital in Levuka, a town that dates its earliest residents to the 1840s. Many of the characteristics of urbanisation in the Pacific region are evident in the form and process of urbanisation in Fiji. The trends of internal migration found in the region, from outer islands to inner islands, from small to large
islands, from inland mountains to coastal plains and from rural to urban, are all evident in the process of urbanisation in Fiji. In addition to this migration, the natural growth of the urban population and the incorporation of formerly rural areas in to the peri-urban areas of cities and towns have contributed to the urbanisation process.

2.1.4 Early urban settlements

The original capital of Fiji was located in Levuka, and founded in 1874 with the cession of Fiji to Great Britain. Before that, the town had been one of a number of urban centres in the Pacific region, catering to the needs of the early European settlers in the region. Levuka existed first as a repair and supply stop for whaling ships sailing to and from the rich whaling grounds of the Southern Ocean (Gravelle 2000). The start of commercial agriculture and trading saw the beginnings of more concentrated and mixed settlement patterns. Levuka was the first, and for a while the largest, urban settlement in the country. The protected harbour and narrow coastal strip saw the development of a small town, much of which remains the same today. It was this lack of land for further expansion that prompted the colonial government to move the capital to its present site in 1882 (Derrick 1950).

The city of Suva has its beginnings in a contentious agreement between the indigenous chief, Ratu Seru Cakobau, and the Polynesia Company. The original village of Suva was located on the foreshore on the western side of the peninsular, in the area now occupied by the Botanical Gardens and Government House. The inhabitants were moved to a new village site on the Lami Bay, now know as Suvavou (Schutz 1978).

The entire Suva peninsular, as far north as the Waimanu river, was acquired by the Polynesia Company in the 1860s from Ratu Seru Cakobau, in return for the payment of compensation claims by a succession of early traders. The Polynesia Company then embarked on a series of agricultural ventures, planting cotton and sugar for export (Moses 1982). While none of these were able to produce much profit, the area became the site of a small European settlement. When the colonial administration decided to look for a new site for the capital, the Polynesia Company offered to sell the land cheaply. In 1882, the capital was established in Suva, on a square mile of land around the mouth of the Nabukalou creek (Quanchi 1977; Moses 1982).
2.1.5 Defining urban areas in Fiji

Early census reports for Fiji include references to towns with legislated local government and de facto towns and settlements that did not have local government, but had the economic and social characteristics of townships. It was not until the 1966 census that an attempt was made to systematically distinguish between urban and rural areas, using precise urban boundaries. Since then, subsequent census reports have recognise four types of settlement as urban (Bureau of Statistics, 1997):

- cities – settlements with municipal government and a population exceeding 20000
- incorporated townships – settlements with legislated municipal government
- unincorporated townships – generally regional centres of administration or commerce
- urban areas – built up areas adjacent to towns where a significant proportion of the population is engaged in non-agricultural activities

Based on these categories, enumeration area zones are delineated, defining the boundaries for classifying the population during census counts. While these boundaries are able to differentiate urban areas by population, there are few other spatial measures of urban boundaries. Municipal boundaries mark the limits of responsibility for town and city councils, but these often have little relationship to the actual land use and human activity taking place.

2.1.6 Urbanisation in the Greater Suva area

The Greater Suva area is defined, for the purpose of this study, as the continually built up area stretching from the western end of Lami to the south-eastern end of Nausori town. This continuous area contains the towns of Lami, Nasinu and Nausori, the city of Suva, and a numerous peripheral settlements and villages. With a total area of approximately 75 square kilometers and a population of 18000, it is the largest continuous urban agglomeration in the Pacific region.

The town boundaries of Suva were officially established in 1881 (Bloomfield 1967) defining an area of 1 square mile from Albert Park in the south, to Walu Bay in the north, and inland a distance of approximately a mile. These boundaries remained until Suva was declared a city in 1952, at which time the boundaries were extended to approximately their present position (Bakker and Walsh 1976)
From the original township in what is now downtown Suva, extensive settlement has spread out along the three main roads out of the city, namely the Queens road, the Princes Road and the Kings Road. Of these three, development along the Kings road has been the most extensive, with the town of Nasinu the result of this rapid change. This ribbon development has been assisted by the construction of a number of large institutions along these major roads. The Tamavua Hospital and Fiji School of Medicine were built along the Princes Road following the Second World War. Along the Kings road the Nasinu Teachers’ Training College and extensive public housing developments contributed to the urban development in the area. Along the Queens Road the cement works, and more recently the fisheries operations at Lami have contributed to development in these areas (Bakker and Walsh 1976)

The town of Nausori developed in close association with one of the oldest sugar mills in the country, which operated on the bank of the Rewa River from 1882 to 1959. The construction of the Rewa Bridge in 1939 opened a direct road link to Suva along the Kings Road and Princes Road, and fostered further growth in the town. Further developments in the post-war
period such as the opening of the Nausori Airport and the Koronivia Agricultural School also contributed to the growth of the town. Nausori was proclaimed a township in 1931, with boundary revisions in 1954, 1961 and 1973 (Bloomfield 1967; DTCP 1975).

With the shift in sugar production to a more suitable climate in the western part of Viti Levu in the 1950s, the sugar mill at Nausori was closed. This resulted in a significant amount of commuting between Nausori and Suva as people travelled in to Suva to work in expanding industrial and service sector in the city. The growth of domestic air travel, and a limited amount of international air traffic in to Nausori airport has also contributed to the increased amount of travel between Nausori and Suva.

The town of Lami was established in 1977, having previously come under the jurisdiction of the Suva Rural Local Authority. While Lami had existed as a distinct urban centre for many years before it was declared a town, the delay in formalising this process was due to the difficulties in defining the Fijian villages close to the town area. While Lami initially functioned as a retail centre for surrounding villages and settlements, recent developments have seen the construction of an industrial park and important fisheries and marine operations on the shorefront (DTCP 1998)

Nasinu town is the newest town in Fiji, having previously been administered under the Suva Rural Local Authority. The area was declared a town in 2000, with discussion still underway to finalise the exact boundaries. Nasinu is a densely populated, primarily residential town with a number of small commercial and industrial centres. The population is centred around a number of public housing subdivisions, administered by the Housing Authority of Fiji. In addition to these, there are a number of crown leased housing subdivisions, and freehold (privately owned) housing subdivisions. A number of government services and industries are also located within the boundaries of Nasinu town. These include the Housing Authority’s headquarters, the Land Transport Authority headquarters, the Kinoya Sewerage Treatment Plant, the Kinoya Power Station, the Fiji Military Forces’ Queen Elizabeth Barracks and The Fiji College of Advanced Education (a teacher training college) (DTCP 1983).

2.1.7 Patterns of urban growth in the Greater Suva area

Much of the growth of the Greater Suva area in the last 50 years has occurred through the linking of a number of smaller urban and peri-urban settlements spread along the main roads
heading west to Lami and northeast to Nausori. As the population statistics for the last 30 years show, the population within the established municipal boundaries has remained fairly constant, with most of the growth taking place in the peri-urban fringe. This is especially apparent for Suva and Nausori, and is accounted for by the rapid growth of the intervening area, much of which is now Nasinu town.

Table 2-2. Population growth of the urban centres of greater Suva since 1966.

<table>
<thead>
<tr>
<th>Year</th>
<th>Suva City</th>
<th>Peri-Urban</th>
<th>Total</th>
<th>Lami City</th>
<th>Peri-Urban</th>
<th>Total</th>
<th>Nausori City</th>
<th>Peri-Urban</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>63628</td>
<td>54199</td>
<td>117827</td>
<td>5262</td>
<td>7559</td>
<td>12821</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>69665</td>
<td>71608</td>
<td>141273</td>
<td>8110</td>
<td>16707</td>
<td>12398</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>77366</td>
<td>90609</td>
<td>167975</td>
<td>10556</td>
<td>18928</td>
<td>15873</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: (BoS 1998)

The Greater Suva Urban Structure Plan (1975) proposes the creation of an urban corridor between Lami and Nausori, with the aim of decentralising industrial and commercial activity away from the central Suva area. The basic form proposed is the development of the Nasinu area, which has occurred to some extent. This development has not, however, significantly alleviated the traffic congestion in central Suva, which continues to be the service and retail centre of the area (DTCP 1975).

With no foreseeable shift in the primacy of the greater Suva area, its continued population growth appears to be certain. Most of this growth, both in terms of population and spatial expansion and development will take place outside the boundaries of the city itself, requiring planning on a regional scale to control and coordinate changes and developments in the increasingly important satellite towns and fringe settlements (Whitelaw 1964; DTCP 1975).

2.2 Urban applications of GIS

The uses of GIS in urban environments are many and widespread. Various attempts have been made to categorise them, with a number of similar themes emerging. These are focused around three main areas namely land management and administration, planning models and simulation techniques, and visualisation methods.
Each of these methods uses various aspects of GIS to assist in achieving their goals. Land management and administration applications were early examples of GIS applications, where the large amounts of attribute data collected and stored by various municipal authorities were linked to spatial representations of property and administrative boundaries (Huxhold 1991).

The rapidly increasing amount of spatially referenced data lead to a convergence between aspects of urban modelling research and GIS. Urban modelling and simulation had developed separately from GIS, with techniques, methods and data developed by researchers in the field. The availability of spatially referenced data through GIS led to efforts to converge aspects of the two fields (Sui 1998).

A third strand in the development of urban applications of GIS emerging in the field of visualisation, in particular in large scale, 3D visualisation. The richness of data and the increasing computing power enabled progress to be made in techniques to visualise spatial data in ways other than the traditional plan view of the map sheet. This strand of GIS applications sits at the interface between a number of subjects such as urban planning, architecture and urban design, but functions as the source of much of the underlying data (Batty, Dodge et al. 1998).

Recent developments in remote sensing technologies, in particular the lower cost and higher resolution imagery generated by commercial imagery providers is adding a new dimension to the use of GIS in the urban environment (Longley 2002). Progress in satellite technology has increased the spatial and spectral resolution of imagery to make it increasingly competitive with traditional aerial photography for high accuracy mapping of urban environments. Image analysis and classification techniques have contributed to the increasing accuracy of automatic delineation of many urban land cover and land use categories.

2.2.1 Land information systems

The early efforts to present GIS for applications in the management of urban information concentrated on a systematic approach to the handling of information within local government organisations. The main aspect of this was the pyramid structure of management, in which information was generated at the operational level, assessed and interpreted at the management level, and used for forward planning and decision making at the policy level.
While many of the early applications of GIS in urban information management focused on North American and European examples of local government operations, they laid the conceptual foundations for future GIS implementation in urban management programs. Some of the early applications included map production and updating, building inspection and inspection workload balancing, waste collection routing and business license policies (Huxhold 1991).

It was recognised in the early stages of GIS implementation that one of the major technical hurdles that had to be overcome was that of linking the large amounts of non-spatial attribute information to a geographically referenced location. A number of geo-coding processes were used, including street segmentation and parcel codes. One of the main challenges in this process was combining the many different spatially referenced datasets within a common geographic framework. In the US, this was significantly aided through the use of national standard spatial data structures such as ZIP codes and TIGER (Topologically Integrated Geographic Encoding and Reference System) and GBF/DIME (Geographic Base File / Dual Independent Map Encoding) files (Broome and Meixler 1990).

Various technological changes have fostered the adoption of GIS by municipal authorities, enhanced its application for multiple purposes, and increased the affordability of system implementation. First, distributed computing environments, incorporating local area networks and network file systems, have increased flexibility and reduced redundancy for both data storage and software. Second, the introduction of personal computers powerful enough to process large database, have enabled the storage and manipulation of highly detailed and extensive spatial data layers such as individual property parcels. Thirdly, low cost, user-friendly desktop GIS software has allowed a broad range of local government staff to utilise GIS (Korte 1997).

As GIS technology has spread, so has the creation of and access to, spatial and spatially referenced data. One of the most significant developments in spatial data in urban areas has been the creation of property parcels databases by many municipal and government GIS and mapping programmes. Often spearheaded by an assessment or engineering department, the construction of a digital parcel base map can incorporate older computerised Land Information Systems (LIS) data (which are based primarily on the parcel record), and provide
new tools for the display and analysis of land related data in a spatially explicit manner. Such land records modernisation is now widely in progress in many developing countries, and parcels are becoming standard elements in the GIS of most municipal jurisdictions (Kollin, Warnecke et al. 1998).

While a number of methods exist for spatial representation of parcels, such as points and grid cells, a true parcel based GIS incorporates a fully digitised layer of parcel boundaries, allowing the parcels to be represented as discrete polygons. As such, the parcel polygon offers many advantages over parcel point or grids, including enhanced display and map production, and the ability to consider site level details necessary for a variety of analytical operations. The conversion of parcel maps to digital format is generally accomplished either through digitising lines on paper maps, or constructed directly from deeds and survey information using coordinate geometry and aided by alignment with planimetric or orthophotography layers (Donahue 1994). The parcel layer may also be derived from previously developed digital CAD (Computer Aided Design) drawings, commonly used by engineering departments since the 1980s. Regardless of what method is used to spatially represent the parcel layer, what is of fundamental importance is the assignment of a unique parcel identification number, which can be used to link the spatial feature to individual land records and other parcel specific data (Huxhold 1991). A related and useful parcel identifier is a standardised address file, which identifies parcels by street address rather than a parcel identification number (Donahue 1994).

GIS functionality (such as spatial data creation, editing, and management) is crucial to managing parcel data. Parcels are notably dynamic entities, especially in urbanising areas where frequent changes result from boundary adjustment, subdivision and land assembly. A major function of parcel based systems is maintaining the on-going consistency of the parcel base map with land records (Moudon and Hubner 2000).

GIS also facilitates linkages between disparate land data attributes through the use of common geographic references such as parcel identification number, standardised street address or x-y coordinate. The use of parcel identifiers is not new, as non-spatial land information have long used parcel identifiers to link tabular data. What parcel based GIS does offer is the efficient storage and retrieval of data spatially referenced to the parcel, with
the benefit of using the parcel itself as an interactive index for retrieval, query and aggregation of the land for various operations (Webster 1993).

The rapid increase in computing power, and the dissemination of GIS and spatial data to municipal governments and planning authorities has resulted in the almost ubiquitous use of land information systems in urban areas. While these systems provide an efficient framework for the storage and management of spatial and attribute data, the increasing sophistication of GIS software has given those working with the data to produce more realistic visualisations and simulations of their data, which in turn can contribute to better informed decision making and planning. This represents a fundamental shift in the use of GIS, from being a data storage and management tool, to becoming part of a decision support system.

2.2.2 Visualisation and simulation of the urban environment

GIS provides an efficient and powerful environment in which to store and manage spatial data, but it is the analytical use of this data that allows it to realise its true potential. This is achieved in two main ways. Firstly to visualise data by rendering it using methods other than the traditional plan views associated with map sheets. Secondly, to attempt to predict the changes that will take place as urban areas expand and grow through simulation techniques (Clarke and Gaydos 1998). While GIS has a long history of managing urban spatial data (as described above), the visualisation and simulation aspects of urban modelling using GIS are more recent developments.

The visualisation aspect of urban modelling has traditionally been a 2-dimensional processes, in which thematic maps based on the attributes of the urban spatial data are created to visualise the spatial distribution of various phenomena across the urban landscape. More recently, 3-dimensional visualisation tools have been developed allowing for more realistic visualisation of the urban environment. While 2D thematic maps have long been valuable tools for urban geographers, the realism of 3D visualisation models has brought together GIS, architecture and urban design, under a common spatial framework (Batty, Dodge et al. 1998). 3D visualisation tools have long been an established part of CAD and engineering, but it is only more recently that 3D GIS has given modellers the ability to access the attributes of the data, while viewing it in 3 dimensions. Software products such as Environmental systems Research Institute (ESRI) 3D Analyst, MapInfo Vertical Mapper, and InterGraph Terrain Analyst put 3D visualisation tools on the desktop.
3D GIS technology is useful to many GIS applications, and especially so in urban environments for the simple reason that so much of the urban environment exists in the vertical dimension. In rapidly urbanising areas, much more building takes place vertically rather than horizontally, and it is becoming increasingly important to be able to locate attributes based on their vertical location as well as their horizontal location. Locating residents in high-rise apartment towers and businesses in office blocks require the use of data in the vertical dimension (Evans and Hutson-Smith 2001).

Current 3D GIS products render the 3D views using the vertical attributes from the underlying data, which are still stored in a 2D model. The rendering process projects the data in the vertical dimension (based on its height attribute) and textures it using a variety of pre-defined textures and styles. Much of this technology has come from the computer gaming and special effects industries and has been made possible by the vast improvements in computing power. While these techniques produce visually impressive images and fly-through sequences, the underlying data structure is that of a traditional 2D GIS. Research is currently underway to create 3D topological data models and spatial representations to produce true 3D GIS, rather than the current 2½D representations (Zlatanova, Rahman et al. 2002).

At present, a number of methods exist to produce 3D visualisation from spatial data, which can be divided into two broad categories (Batty, Chapman et al. 2000). Firstly, 3D CAD models of cities are by far the most common example of 3D urban models, depicting scenes from the built environment in three dimensions with varying degrees of attention to detail and artistic rendering. Usually, the models have no functionality beyond display (i.e., they are not linked to a spatially referenced database, nor capable of displaying the results of searches and queries performed on them). Secondly, 3D GIS models of cities are identical, in many cases, to the CAD models discussed above. The difference, however, lies in functionality. The incorporation of a GIS underpinning a CAD display model enables users to perform spatial queries of the buildings and built space depicted in the model environment. A GIS, essentially, acts as a spatial database with a graphical interface for performing queries, operations, and manipulations on data in a spatial plane (Delaney 2000).
The large volume of spatial data managed by GIS has also contributed to the development of research in to the simulation of urban patterns and processes, traditionally the domain of urban planners. During the 1970s and 1980s, GIS and urban planning developed in parallel, with few interactions between them. During the 1990s, closer integration began to take place, as part of the GIS community’s attempt to improve the analytical capabilities of GIS. Various urban modelling techniques have enabled GIS users to go beyond the data inventory and management stage to conduct sophisticated simulation, by providing new platforms for data management and visualisation (Goodchild, Haining et al. 1992).

Within an urban system there are many different sub-systems including, urban networks (transportation and communication etc.), land use, workplace infrastructures, housing infrastructures, population, employment, goods transport, travel and the overall urban environment (Wegener 1994). Integrated urban models are built to investigate the interrelationships between some or all of these sub-systems as they change with time and provide an abstract world in which theories relating to urban process may be investigate to gain a better understanding of such processes. They also can be used as a tool to evaluate the effect of various policy decisions on an urban system or sub-system.

An integrated urban modelling environment needs to provide access to a variety of modelling techniques that can be applied to data sets stored in a variety of data models (and underlying data structures). The components of such an environment should include (Yates and Bishop 1997):

- a database management system that includes tools to support the collection, storage and validation of data, the transformation between data models, the translation of a data structure for a given model, and the ability to retrieve data from storage;
- a model management system that provides tools for the description, calibration, and validation of models; and
- support for the visualisation of the data sets and the output of models.

While current GIS have extensive capabilities for the first and third of these aspects of urban modelling it is the process of integration with the actual urban model that has proved the main challenge. GIS and urban models have been integrated in a variety of ways, which can be categorised in to four main groups (Anselin, Dobson et al. 1993). The first method is to
embed GIS-like functionality in urban modelling packages. This method is usually adopted by developers of urban modelling software, who use GIS as a mapping tool. This flexibility allows them to incorporate changes in urban modelling theory. The main problem with these packages is that they use their own data structures and their data management and visualisation capabilities are in no way comparable to those available in commercial GIS packages. The second method is to embed urban modelling in GIS software by GIS software vendors. Some of the larger GIS software vendors are including some urban modelling functionality in their software. Examples of this include ESRI Spatial Analyst and Network Analyst. This approach builds on the top of the sophisticated GIS functionality of these packages, but the urban modelling capabilities are simplistic. The third method is a loose coupling between standard GIS software and urban modelling, or statistical analysis software. In this approach, GIS and urban modelling are integrated through a data conversion and exchange process. The data conversion and exchange process can be difficult and tedious, but the absence of any complex programming means that this is the method preferred by most users to conduct modelling. The fourth method is a tight coupling between GIS software and urban modelling software. The use of programming and scripting languages mean that users now have the ability to customise aspects of the GIS to their specific modelling requirements (Sui 1998).

The first two approaches put the task of integration between the GIS and the urban model in the hands of software developers, while the third and fourth approach leaves this to the individual user. Although GIS software vendors are increasingly recognising the importance of analytical and modelling capabilities, most of the recent GIS-based urban modelling has been made using loose or tight coupling approaches (Anselin and Bao 1997). This has led to a number of criticisms of the modelling process, based on the representational limitations of existing spatial data structures, and the fundamental assumptions of the modelling methods themselves. GIS has its roots in digital cartography and image processing, with the development of spatial data to date relying on a limited map metaphor (Burrough and Frank 1995). Therefore, the representation schemes and analytical functions are geared towards map layers and geometric transformations, implicitly forcing a segmentation of geographical features (Rapper and Livingstone 1995). This map metaphor, is based on an implicit conceptualisation of space based on Newtonian mechanics and has become the spatial foundation for modern GIS (Couclelis 1999). This absolute conceptualisation of space has forced space in to a geometrically indexed representation scheme using planar enforcement.
In contrast, embedded in various urban models is essentially a relative conceptualisation of space, manifested in various spatial structures, spatial dynamics and spatial organisational models. This relative view of space is not compatible with the notion of space built in to commercially available GIS, as inert assemblies of polygons or lattices of raster cells. Thus, while it is technically possible to plug urban models into GIS using the strategies previously outlined, they cannot be considered to be truly integrated because of the different spatial data representation schemes involved (Abel, Kilby et al. 1994). This lack of consistency between the data structure and the analytical models has led to new direction for research, concerned with more appropriate spatial representation methods under the banner of Geographic Information Science (Sui 1998).

While this line of inquiry is concerned with developing more appropriate data models, a parallel direction has been taken in developing the modelling techniques involved in urban simulation. Traditional urban models tend to be based on gravitational concepts of spatial interaction, where Newtonian mechanics and Keynesian economics are the driving forces behind interaction between the various aspects of urban systems (Foot 1981). This mechanistic approach to urban processes, where urban areas are conceptualised as machines, has recently given way to a more biological approach, where cities are conceptualised as organisms. Fractals, neural networks and cellular automata are being increasingly used to develop more representative urban models (Torrens and O'Sullivan 2001) (Batty and Longley 1994).

These aspects of the use of GIS in relation to urban management and planning outline the general state of applications and activity in the field. While advances in modelling techniques and the search for more representative data structures will remain the focus of the research agenda in the developed world, in the developing world, the actual implementation of GIS will continue to be the major challenge. In the context of the developing world, more fundamental aspects of GIS need to be carried out initially, such as data collection and the development of efficient and appropriate data management methods. Only then will the visualisation and simulation models described become available.

2.3 Diffusion and implementation of GIS

The ability to innovate is generally regarded as fundamental to organisational survival. Governments and organisations around the world continue to expend considerable resources
in the search for technological innovations and novel techniques, which it is assumed, will increase industrial and administrative competitiveness. However, many seemingly good ideas remain in the workshops of their inventors, while other diffuse rapidly through society. This leads observers to question the extent to which diffusion is dependent on the inherent technological characteristics of a particular innovation. At least as important appear to be the cultural, organisational and institutional contexts in to which such a development is to be embedded (Bijker, Hughes et al. 1987; Dunlop and King 1991). It is therefore crucial that consideration is not only given to the elegance of the technology but to the interrelationships between organisations and innovations if greater understanding of how a potentially good idea becomes a facility taken for granted (Campbell and Masser 1995).

This section will review the growing body of research that is seeking to improve the understand of the way technologies, and in this case geo-spatial technologies such as GIS, diffuse through societies and are implemented by governments and other organisations. GIS, like much of IT, has been promoted as a way of improving efficiency by reducing the duplication of data sets and ensuring that all sections of an organisation have access to the same up to date information. GIS has also been envisaged as contributing to organisational effectiveness, through the provision of basic data, and stimulating more complex analysis that would enhance decision making at various levels in an organisation. Implicit within these views of IT (including GIS), are assumptions about the central role of computers and technology in society, and a shift in economic emphasis from mechanistic industrial processes to programmable computer processes (Toffler 1980).

Despite the myriad of claims about the potential opportunities that will result from the introduction of new forms of IT such as GIS, relatively little attention has been paid to the impacts the technologies are having in practical terms. Attention has instead been focused largely on enhancing the technical aspects of IT. These technical innovations are of little value if they are problematic to implement or are considered of little relevance to potential users. Expectations of the utopian conceptions of technology are increasingly challenged by evidence that suggests that technical elegance is no guarantee for widespread diffusion. Studies investigating the introduction of computer based systems have shown a variety of marginal gains, unforeseen problems and complete abandonment of a project, more often than complete success (Moore 1993), suggesting that technology itself is one factor of many influencing the success of a particular innovation.
2.3.1.1 Diffusion of GIS

The early work on diffusion theory with regard to technical innovations can be traced back to work carried out in rural agricultural technology in the 1940s (Rogers 1993). The main elements of diffusion can be defined as an innovation, which is communicated through certain channel, over time, among members of a social system. Five attributes of innovation are; relative advantage, compatibility, complexity, trialability and observability. Other factors such as result demonstrability (the degree to which the results of using the technology can be communicated to others) and visibility have also been suggested (Moore and Benbasat 1992).

The diffusion of GIS technology has become part of a wider field of research in to the diffusion of IT in general. From a geographical point of view, the nature and process of this diffusion has been studied from a spatio-temporal perspective, relating the spread of the diffusion to the fundamental geographical concepts of space and time. Other aspects of the diffusion process which have been considered to influence the diffusion processes include the nature of the technology, the economic costs and benefits associated with the perceived increased productivity, and more recently, the social and institutional environment in which the technology is introduced (Campbell 1996). These have been expressed as three broad perspectives, namely technical determinism, managerial rationalism and social interactionism.

Technological determinism assumes that the advances inherent in a technological innovation are the main force driving the diffusion of that technology. In effect, the innovation drives itself because it is, by definition, better than in predecessor. During the first major boom of GIS in the early 1990s, this was often the perspective from within the industry, where the assumption that more powerful and more user-friendly applications would automatically result in increased and more effective use (Innes and Simpson 1993). Under this model, the acquisition of a technology generally assumes that it would become ubiquitously utilised. Failure for this to occur could be the result of either a shortcoming of the technology (for which a technical fix would be the solution), or the incompetence of the user (which could be remedied through better training and awareness raising) (Kling 1991).
Managerial rationalism differs from technical determinism in that the introduction of an innovation is not solely technical in nature, but is the consequence of rational strategies laid down by managers in the organisation. This scientific approach to management is based on the process of pre-planning and strategy formulation, represented by a sequence of stages leading towards the utilisation of a system of technology. Eason (1988) describes this as the data processing approach, consisting of a number of phases from projection selection through feasibility study, system analysis, requirements specifications, system design, construction, trial and ending with full implementation. While this approach often produces perfect systems on paper, based on technical and managerial parameters, the lack of consultation with users has been a major criticism.

This managerial approach has often been behind the thinking of many GIS programs. Because of the ability of GIS to integrate data from a variety of sources, a corporate or enterprise approach is usual taken when building a GIS. This is aimed at ensuring that the data from different parts of the organisation is made available to the GIS and becomes integrated in it (Bromley and Selman 1992).

While both of these approaches do contribute significantly to the process of diffusion of GIS, the fact that this diffusion has not happen at a constant rate has resulted in alternative theories being developed. This is especially true for environments that underwent very similar experiences in terms of exposure to the technology and similar economic situations, but in which the diffusion of the technology was widely varied. The example of varied diffusion of GIS technology in Europe in the early 1990s has been the focus for research and the development of alternative theories of diffusion (Campbell 1993; Masser, Campbell et al. 1996).

Social interactionism is a term that has been used to describe a wide variety of theories in which the basic premise is that technology is socially constructed. The diffusion of innovations is seen as the result of interaction between the technology and its users within particular cultural and organisational contexts (Reeve and Petch 1999). This approach suggests the process of diffusion will be complex and problematic, the outcome of which is regarded as resulting from the socially constructed values underlying adoption rather than the technical characteristics of the innovation (Campbell 1996).
This conception of organisations as unique cultures is implicit in much of the discussion concerning social interactionism. This has implications for the diffusion of technologies because the unique nature of organisations means that universally applicable strategies are impractical. Many of the problems associated with a new technology often have little to do with the technology itself, but rather stem from the application of the technology in an inappropriate manner or environment. The management of this kind of change needs to be nurtured rather than imposed and controlled (Handy 1993). Understanding the organisational context in to which a technology is to be embedded is therefore regarded by the social interactionism perspective as crucial to system development.

The underlying goal of the social interactionist model of diffusion is to gain organisational and user acceptance for the technology, and not simply to achieve a technically operational system. Under this model, it is assumed that routine use of the technology will not take place until the system meets the fundamental needs and capabilities of users and has obtained their commitment and support. As a result, emphasis is placed on participative approaches to implementation typically through by user-centred design methods (Eason 1988). Through this approach, users are more likely to feel an ownership for the system, and will therefore make more use of it and continue to develop it.

The most notable feature of the social interactionist perspective in relation to GIS is its virtual absence from the literature in this field, either in terms of an exploratory framework or as a basis for implementation. Conference proceedings and industry publications concentrate on creating technical solutions with little regard to the environments in which the technology is expected to operate. This focus on technical orientation would seem to be partly symptomatic of the relative newness of GIS as a commercial product (Budic 1994).

2.3.1.2 GIS Implementation

Innovations depend on the process of implementation to become absorbed in to the organisational context in which they have been introduced. Traditionally, implementation has been envisaged as one phase within a linear progression from initial awareness about an innovation, through to its routine use i.e. the diffusion of the innovation. While this has been often been considered an oversimplification of the process, the critical feature remains one of managing change (Campbell and Masser 1995).
Huxhold (1993) uses examples from research in to information systems implementation, under the premise that information systems are not fundamentally different from GIS. The results indicate a number of conditions that must be met in order for integrated information systems to be successfully implemented and adopted and that these conditions appear to be similar to the conditions found in the GIS literature on the importance of organisational issues in GIS implementation and use. The conditions are summarised as follows.

- Existing complex relationships among all units of the organisation must be analysed from an enterprise-wide perspective.
- The goals of all participants of the integration effort must be in alignment and the participants must perceive the effort as a solution to a specific problem or issue.
- Top managers must not only be in control of the policies affecting the integration effort, but must also be affected by its results.

A further issue of importance to the role of GIS in urban planning and management is the manner in which GIS is implemented in terms of a corporate (sometimes known as ‘enterprise’) or departmental approach (Campbell 1993). The corporate or enterprise approach is generally accepted as being the more rational method, as it reduces implementation costs and encourages enterprise-wide cooperation in system maintenance and development. On the other hand, the departmental approach tends to lead to a break up of data and workflows and is considered to be a less productive method of implementation.

Table 2-3. Comparing enterprise and departmental approaches to GIS implementation.

<table>
<thead>
<tr>
<th>Corporate approach</th>
<th>Disadvantages</th>
<th>Departmental approach</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration of data sets</td>
<td>Variations in priorities between departments</td>
<td>Independence</td>
<td>Departmental isolation</td>
</tr>
<tr>
<td>Increased data sharing</td>
<td>Differences in ability to exploit GIS technology</td>
<td>Control over priorities, form and accessibility of information, technical specialists and equipment</td>
<td>Lack of support in terms of finance, technical specialists and training</td>
</tr>
<tr>
<td>Improved access to information</td>
<td>Differences in levels of awareness and spatial data handling skills</td>
<td>Clear lines of responsibility</td>
<td>Absences of authority-wide benefits including lack of system and data compatibility</td>
</tr>
<tr>
<td>More informed decision making</td>
<td>Disagreements over access to information, leadership, data standards, equipment and training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased efficiency due to reduced duplication leading to time, staff and cost savings</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: (Campbell and Masser 1995).
The discussion of the advantages of a departmental approach to the introduction of GIS however, assumes the same level of consensus exists at a departmental level as corporate approaches assume on an authority-wide scale. It is important to recognise that individual departments are themselves divided into a large number of separate sections, each with separate area of responsibility and consisting of individuals whose underlying goals and motivations may be in conflict. The impact of social and political processes on the experience of implementing GIS must therefore be examined at a departmental as well as an organisation-wide scale (Campbell 1996).

2.3.1.3 Variations in GIS diffusion and implementation

The rate and nature of GIS diffusion can also be attributed to the land information and administration environment of the local community in which GIS technology is being introduced (Wegener and Junius 1993). The land information and administration environment is a multi-faceted concept, which includes the traditional form in which land information has been stored and managed, and the use of IT tools and systems to attempt to automate and improve some of these processes. In countries of Europe and North America, two main forms of land information administration exist. Countries such as Germany organise land information by parcel (i.e. the cadastre and titles system), whereas in Britain and the US, land information is organised around the owner in the form of deeds (documents relating to land transactions). The problems with implementing the concept of a ‘universal’ GIS include the following (Junius, Tabeling et al. 1996).

- Data models – not being compatible with local spatial data
- Algorithms – not compatible with local systems and work flows
- Networking – having data available to multiple users with different levels of access
- Data interface – conversion of GIS data to cartographic software due to limited cartographic capability of GIS
- Cost – expensive when bought from outside, but free when developed in-house
- Language – most software is written with English interface, meaning it is not accessible to non-English speaking users

Other factors that have been suggested which also influence the diffusion and implementation process, specifically in municipal organisations include (Rumor 1993):

- data availability problems stemming from the lack of a single agency charged with collecting and maintaining spatial data
- need for organisational change
- need for long term investment plans
- lack of skilled personnel
- lack of standardisation and coordination

In recognition of these problems a variety of possible solutions are suggested. The central theme of these solutions acknowledges that while GIS technology has often been considered a tool to support management decision-making processes, it is also possible to use it for operational activities. Applications can be developed which aid at departmental levels in many technical activities. The use of GIS for everyday functions can be a key factor in the success of the introduction of GIS technology into organisations (Masser and Graglia 1996). The 'grand design' approach is rarely the appropriate way to introduce GIS technology into public organisations (and it probably is not a good approach for introducing any kind of innovation). An incremental approach has demonstrated itself to be far more effective. The retention of the global design as a framework within which each single application has its place and the development of well defined, specific, rather simple yet integrated applications can prove to be the best strategy (Rumor 1993)

2.3.1.4 Inter-organisational GIS

Much of the research into GIS implementation and development has focused on the use of GIS within single organisation and departments. There has been much less emphasis on the process of GIS at the inter-organisational level. Various factors have increased the level of inter-organisational GIS activities, and some general trends are beginning to emerge.

One of the main factors influencing the increase in inter-organisational GIS is the issue of redundancy in data. With many organisations working with spatial data, and an increase in GIS activities in both public and private sectors, there is an increased risk of the creation and use of multiple sets of essentially the same data. This leads to problems of consistency and increased costs in the process of collecting and managing the data. In recognition of this, a variety of mechanisms have been developed to try and reduce the level of redundancy, among them the concept of inter-organisational GIS (Eichelberger 1986; Harralson, Sheldon et al. 1988)
In inter-organisational GIS, one of the main aspects of the process is in the sharing of data. This data sharing can take a number of forms, from the manual exchange of digital data between organisations, to fully shared and centralised GIS and spatial data facilities. The process of data sharing has been supported to varying degrees by the local and national institutions and data sharing policies. This has been especially true in the US, where development of national databases such as GBF/DIME and TIGER has given local and institutional GIS activities a nationally consistent spatial framework within which to structure their systems. More recently, the National Digital Geo-spatial Data Framework and Clearinghouse, a federal spatial data policy and infrastructure has increased even more the range of GIS data sharing (Frank, Goodchild et al. 1996).

Both technological and organisational difficulties are likely to be encountered in building inter-organisational GIS and sharing spatial data. The following specific problem areas have been highlighted (Campbell and Masser 1995):

- variations in the priorities between participants
- differences in the ability to exploit GIS facilities
- differences in the level of awareness and spatial data handling skills
- agreements over ownership, access to information, leadership, data standards, equipment and training.

From a technical aspect, a similar variety of problems have been identified (Nedovic-Budic and Pinto 1999). These include:

- problems in coordinating system requirements
- lack of common data definitions, formats and models
- differences in data quality
- costs involved in network and the physical transfer of data

While these problems remain to varying degrees in different environments, they have been alleviated to some extent by technical solutions towards interoperability and open systems, distributed data processing, integration of national databases and the use of the internet.

A useful conceptual framework for better understanding various aspects of inter-organisational, is suggest based on four factors. Firstly, the inter-organisational context,
which has to do with the intensity and the quality of inter-organisational relationships, interdependence, resources, structure, stability, culture, politics and leadership. Secondly, the motivation for inter-organisational GIS, which can range from economic and political to technical arguments. Joint effort can be the result of a sense of duty, common interest or exchange inducements, and can be pursued as voluntary or mandated. Thirdly, the coordinating mechanisms for inter-organisational GIS are manifested through established structures, processes and policies. Structures can be defined as the channels, direction and method of information flow and the level of shared components (such as data, hardware personnel). The process of coordination can be undertaken through standardisation, joint planning or mutual adjustment, and formal or informal policies are established to address data related issues, responsibilities, ownership, contribution and incentives. Finally the outcome of inter-organisational GIS activities can be assessed using criteria such as efficiency, effectiveness, decision making impact, societal equity and public service (Nedovic-Budic and Pinto 1999).

As these factors show, efficient inter-organisational GIS, in common with many of the issues highlighted in respect to GIS diffusion and implementation in general, is a complex process. Both technical and institutional factors combine to determine the effectiveness with GIS operations run at department, enterprise and inter-organisational scales. The next section outlines a method by which data distribution and management can be structured to improve this efficiency.

### 2.4 Spatial data infrastructures

The organisation and management of spatial data at the national, and international scale has in recent years embraced the concept of Spatial Data Infrastructure (SDI). SDI has emerged in a number of developed countries, based on earlier models for the co-ordination of geographic information (McLaughlin and Palmer 1999).

The development of SDI grew from institutional responses to cooperation on integrated mapping, the multipurpose cadastre concept, and the nodal approach to integrating land data and information. Organisations championing the concept of spatial data as infrastructure are typically cadastral agencies and national mapping organisations. In the US, SDI emerged from a strategy to create a national multipurpose cadastre (Crouse 1993). Similar developments have emerged from the Land Registration Information System in Canada.
(Sousa 1993) and the digital cadastral databases of Australia (Williamson, Chan et al. 1995). The Ordnance Survey in the United Kingdom is an example of the central role of a national mapping organisation, as opposed to a cadastral agency, in the creation of a SDI (Rhind 1996).

The motivation behind the emergence of SDI in these countries is multidimensional. The following factors are pertinent (Labonte, Cory et al. 1998).

- Maturing GIS industry and market, resulting in greater acceptability, awareness of potential, and the need for access to a more diverse range of data sets.
- Political drive for reformed government - leaner, more efficient, more effective - and the move towards cost recovery and privatisation.
- The move towards a knowledge based economy
- The impact of information and communication technologies (ICT) and the internet in particular, on the market economy and on government services ("joined up government" (Izzard 2000)).

To this list can be added the following, which are of increasing importance in the developing world:

- Technology transfer - the desire to implement and use technology to 'fast track' or 'leap frog' the development process (the lure of new technology).
- The importance of land and land information in the economies and societies of developing countries.

This section will examine the concept and contents of SDI, as it currently exists in developed countries. A catalogue of common components will be defined with a view to assessing the applicability, or otherwise, of a similar spatial data definition for developing countries. The second part of this section will look at some emerging implementations of SDI in the developing world. This will serve as background to this study which will look more closely at the components of SDI that are appropriate for integrated urban applications in Fiji and that meets the needs and expectations of the local GIS user community.
2.4.1 Defining Spatial Data Infrastructure

Formal SDI exist in only a limited number of countries most of which are in the developed world. The following list of national SDIs will undoubtedly expand, as the SDI concept matures and becomes more widely known, accepted and copied.

As the purpose of this study is not to examine in detail the development of SDI around the world, the discussion that follows will be limited to the broad characteristics of the most mature national programmes, namely the US, Australia, Canada and the UK.

Table 2-4. List of countries with formal SDI.

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>DAISI</td>
</tr>
<tr>
<td>Finland</td>
<td>National Geographic Information Infrastructure</td>
</tr>
<tr>
<td>France AFIGEO</td>
<td>White Paper on French GI</td>
</tr>
<tr>
<td>Germany</td>
<td>DDGI</td>
</tr>
<tr>
<td>Hungary</td>
<td>HUNAGI - Hungary sets national spatial data strategy</td>
</tr>
<tr>
<td>Ireland</td>
<td>IRLOGI</td>
</tr>
<tr>
<td>Italy</td>
<td>AM/FM Italia</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Ravi</td>
</tr>
<tr>
<td>Portugal</td>
<td>CNIG</td>
</tr>
<tr>
<td>Spain</td>
<td>AESIG</td>
</tr>
<tr>
<td>Switzerland</td>
<td>SOGI Europe</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>National Geospatial Data Framework</td>
</tr>
<tr>
<td>Antarctica</td>
<td>Antarctic Geographic Data Integration</td>
</tr>
<tr>
<td>Australia</td>
<td>Australian Spatial Data Infrastructure</td>
</tr>
<tr>
<td>Canada</td>
<td>Canadian Geospatial Data Infrastructure</td>
</tr>
<tr>
<td>Colombia</td>
<td>Instituto Geográfico Agustín Codazzi</td>
</tr>
<tr>
<td>Indonesia</td>
<td>National Coordination Agency For Surveys And Mapping</td>
</tr>
<tr>
<td>Japan</td>
<td>NSDIPA - National Spatial Data Infrastructure Promoting Association</td>
</tr>
<tr>
<td>Malaysia</td>
<td>NaLIS</td>
</tr>
<tr>
<td>South Africa</td>
<td>National Spatial Information Framework</td>
</tr>
<tr>
<td>United States of America</td>
<td>National Spatial Data Infrastructure</td>
</tr>
</tbody>
</table>

Source: (Johnson 2000).

Using examples of implementations found in these countries, it can be seen that there are commonly four main components of a spatial data infrastructure (Masser 1998; FGDC 1999). These are:

- institutional framework,
- technical standards,
- fundamental or core datasets, and
- data clearinghouse, including metadata.
Briefly described, the institutional framework covers not only the organisational and human resources, but also the business context and policy relating to the use, dissemination, cost and copyright of data. Technical standards are crucial to the linkage, exchange and integration of data, particularly as the SDI data model is based on a distributed approach to data management and ownership. The fundamental or core datasets are the tangible parts of the infrastructure, the framework or foundation onto which other data can be added. The final component, the data clearinghouse, is the discovery, access and delivery mechanism for third party data sets that are available for wider use.

2.4.2 Reasons for creating a SDI

The common thread of SDI is accessibility of data. Some of the problems that have been identified which a national SDI programme is expected to address, include (Rhind 1997)

- information about the availability of spatial data is difficult to obtain,
- existing data have been collected by different organisations using different spatial, references and to different standards and quality, making such data difficult to integrate,
- data may be collected by government but for various reasons it is not available to other users,
- physical access to data can be problematic.

In general terms these reasons can be categorised and listed as the following benefits (Rhind 1997):

- improve efficiency and effectiveness of government and of government policy and programmes,
- provide new business opportunities and markets through promoting the shared use of geospatial data,
- facilitate and encourage collaboration in the collection, access, provision and use of geospatial data, to reduce costs and wastes, and improve quality and service.

A basic principle is that users of GIS can acquire consistent data sets that meet their requirements.
2.4.3 Aims of SDI

The NGDF mission statement is that it intends “to develop an over-arching UK framework to facilitate and encourage efficient linking, combining and widespread use of geo-spatial data” (Rhind 1997). The Australian SDI includes much broader societal goals and objectives, with a vision that embraces the promotion of economic growth and environmental sustainability (ANZLIC 1996). The NSDI in the US has a similar socio-economic vision “to promote economic development, improve our stewardship of natural resources, and protect the environment, … avoid wasteful duplication of effort and promote effective and economical management of resources by Federal, State, local, and tribal governments” (Clinton 1994). The Canadian SDI has similar broad socio-economic goals in combination with more specific geo-spatial data management objectives (Labonte, Cory et al. 1998).

The conclusion to this brief overview of implementation of SDI in developed countries is that with the move to knowledge based economies, the creation of information infrastructures has general socio-economic benefits as well as more specific data management benefits. Making government more efficient, effective and responsive, and giving nations a competitive advantage in the global economy, are as important as making data more accessible and useable.

Regional, national and even local contexts are important in shaping the development of SDI in a particular country. The impact of regional co-operation agreements and funding mechanisms, the influence of national organisations, and the relationships between different tiers of government can profoundly affect the form and function of any development project, including SDI. Although the organisational context, institutional framework, technical standards and metadata are undoubtedly important aspects of SDI the nucleus of the infrastructure are the fundamental datasets.

2.4.4 Fundamental data sets

A majority of the spatial data infrastructures, and this includes those listed in Table 2.5, recognise the importance of core or fundamental data in the implementation of the infrastructure (Clarke, Holland et al. 1999). Fundamental data is the foundation on which other information is constructed and can include some or all of the following:

- basic data that can be used in applications;
Fundamental data is distinct from 'thematic' data. Thematic, theme or subject data is produced by a user based upon a foundation of the geometric characteristics and spatial qualities of fundamental data. Fundamental data can be considered synonymous with the traditional base map upon which other data is plotted and displayed (e.g. geological features on topographic mapping). However, some SDI programmes widen this narrow definition to include commonly used, consistent, national, and multidisciplinary data sets (ANZLIC 1996; Labonte, Cory et al. 1998; Clarke, Holland et al. 1999). This raises a distinction that is commonly made between fundamental and framework data. The Australian Land Information Group follow the generally accepted classification that framework data are a priority subset of fundamental data (Labonte, Cory et al. 1998). Framework refers to fundamental georeferencing data on which other fundamental data is constructed. The obvious example is the geodetic control network and coordinate reference system. Framework data is fundamental data, but not all fundamental data is framework data.

Table 2-5. Fundamental data sets for various national SDI.

<table>
<thead>
<tr>
<th>Country, acronym, name and reference</th>
<th>Fundamental data sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States of America, NSDI, National Spatial Data Infrastructure (FGDC 1995)</td>
<td>Geodetic control, Orthoimagery, Elevation, Transportation, Hydrography, Governmental units, Cadastral information</td>
</tr>
<tr>
<td>United Kingdom, NGDF,</td>
<td>Basic land and property unit, Geographic names, Postcode, Postcode boundaries, Postcode addresses, Postal address, Administrative boundaries (County, district, ward), Map boundaries</td>
</tr>
<tr>
<td>Canada, CGDI, Canadian Geospatial Data Infrastructure (Geoconnections 1999)</td>
<td>Geodetic reference system, Imagery (Landsat 7), CDAL (Data alignment layer), Roads, Hypsography (DEM), Hydrography, Administrative boundaries</td>
</tr>
<tr>
<td>Australia, ASDI</td>
<td>Primary reference, Geodetic control network</td>
</tr>
</tbody>
</table>
| Australian Spatial Data Infrastructure, (ANZLIC 1996) | Aerial photography  
Satellite imagery  
Administration  
Land parcels/cadastre  
Street address  
Administrative boundaries  
Postcodes  
Place and feature names  
Natural environment  
Soils  
Vegetation  
Biodiversity regions  
Fauna  
Land surface  
Bathymetry  
River catchments/drainage areas  
Streamlines and inland waterways  
Geology  
Mineral resources  
Hydrogeology  
Oceanography  
Climate  
Land systems  
Areas subject to natural hazards  
Built environment  
Cultural features  
Aviation features  
Marine transport  
Road centrelines  
Water, irrigation and drainage networks  
Gas, electricity and communications networks  
Socio/economic  
Census districts  
Demography  
Planning zones  
Rural and urban land use |

Source: (Johnson 2000)

These examples of national SDI show that geodetic control or reference frameworks head the list of most core data sets. The geodetic control network may be defined as a network of points, or a set of known reference positions, used as a basis for positioning other features. The geodetic survey has two main roles. Firstly, it provides a network of control points for positioning and control of other surveys, and secondly, it provides scale and orientation for the construction of maps using projections and grids. Map coordinate systems have assumed broader importance with the advent of digital mapping and GIS. Prior to the widespread use of computerised GIS, the display and analysis of spatial data relied almost exclusively on base mapping grids. Now most GIS software support a multitude of different grid (spheroids and projections). The consequence of this is that users can unknowingly try to integrate two
seemingly geographically similar data sets that are incompatible due the use of different projections. This issue also extends to the use of datums and spheroids.

The definition of technical standards for SDI begins with defining a common co-ordinate reference system based upon mutually agreed geodetic datum and control framework. Standards for basic spatial data have in the past been set by National Mapping Organisations (NMO) through the adoption of published specifications for topographic mapping (Smith and Rhind 1999).

The need for a geodetic reference standard is now more important than ever given the flexibility allowed by most GIS software to pick and choose the co-ordinate system for referencing spatial data. A further complicating factor is the growing use of the Global Positioning System (GPS) that produce co-ordinates in the earth-centred WGS-84 system, which is different from most traditional map based co-ordinate systems. For this reason, geodetic reference systems must top the list of fundamental data sets as is clearly apparent from the table.

2.4.4.1 Fundamental Data - Imagery

All of the national SDI listed in Table 2.5, with the exception of the UK, include imagery as part of their fundamental data. This can include satellite images, and/or aerial photographs (either ortho-rectified, rectified or uncorrected). The value of imagery is manifold and provides a useful tool for various applications. Because many land features can be seen on an ortho-image, it can serve as a backdrop for visual reference purposes, saving the expense of creating vector files of features that are needed only for reference. Imagery that is not geo-referenced nor corrected for distortions is obviously less valuable but nevertheless useful for many applications, particularly where it can be quickly rectified and geo-referenced by the user's software. Satellite or aerial remotely sensed imagery is available in a wide range of resolutions and formats (Barnsley 1999). Not all of these images could conceivably form part of a spatial data infrastructure - most would be better described as user application source data. However, some imagery by the nature of its coverage and wide applicability can be classed as fundamental data. Scale and resolution might vary, but to qualify as fundamental, the image data set must be national in its coverage (Estes and Loveland 1999). For example, the Canadian SDI is proposing to establish national imagery coverage, consisting of ortho-images based on data captured by the Landsat 7 satellite. The level of data
resolution, the availability of panchromatic and multi-spectral data, comparatively low cost, and the absence of rigid rules for data use were compelling reasons why the GIS agencies involved chose Landsat 7 imagery (Geoconnections 1999). For similar reasons, Jamaica is using high resolution IKONOS imagery to update its national mapping operations (SpaceImaging 2001). In some respects it might seem that ortho-image data sets have replaced basic topographic mapping as the contextual background and reference for spatial data. However, it appears that the features depicted on basic topographic mapping are individually rather than collectively being included in fundamental spatial data infrastructure.

GIS applications for different disciplines typically have a recurring need for the same core data sets. These core data sets allow the standard use, display and analysis of spatial data as well as the opportunity to share and exchange data with other organisations. These core data sets are referred to as fundamental data sets, and are built upon the foundation provided by framework data.

2.4.4.2 Fundamental Data - Elevation

Almost all national and regional programmes for SDI include elevation data, in one form or another, as part of their fundamental data. It may be argued that because height above datum is a cardinal component in geodetic computation that elevation, like position, should be classified as framework data. However, not all applications need data that includes a third dimensional component. On this basis, elevation data may be defined as fundamental data - it has a wide variety of applications, but is not essential to the display of spatial data. Elevation data, like imagery, can be provided in a range of scales and resolutions (Smith and Rhind 1999).

As with geodetic reference frameworks, standards are important to the dissemination and use of elevation data, particularly in the choice of datum. Similarly, metadata must inform the user about limitations of quality and accuracy attributable to the methods employed in creating the data set.

2.4.4.3 Fundamental Data - Built Environment

In examining the core data components it is evident that many fundamental data also appear on traditional base topographic mapping. These components of SDI can be grouped in to a
category called the 'built environment', which include transportation (roads, railways, canals), utilities (electricity, gas, telephone networks), and urban centres (built up areas).

In a modern industrial society these data are needed to provide cost-effective services and supplies to the consumer. They are also used for record-keeping, planning, and regulatory control (Yeh 1999). Utility supply, such as electricity, water, telecommunications, and community infrastructure provision, such as roads, railways, are now so fundamental to the well being of society that the operation and management of these assets have come to rely upon the use of GIS and therefore it follows that these attributes should form part of a modern nation's fundamental spatial data infrastructure (Meyers 1999).

2.4.4.4 Fundamental Data - Natural Environment

Environmental data can often be hard to define, and therefore can include extremely large amounts of spatial data. This can result in problems in deciding what data to include when designing a national SDI (Larson 1999). So much environmental data is important to a wide range of users, and it would be a challenging task to identify a small number of data sets that can truly be classified as fundamental. The only common data set of natural resource/environmental character that appears in all the case study SDIs (excluding the UK) is water. This is usually in the form of natural hydrology, including streams, rivers, lakes, reservoirs and coastlines, but not necessarily rainfall data, bathymetry, hydrogeology, for example, which can be classed as thematic data.

2.4.4.5 Fundamental Data - Socio-Economic

'Administrative boundary' is the term usually used to describe the fundamental unit of spatial socio-economic data. This may or may not include boundaries of census zones, which in many developed countries are the primary unit for managing the collection and dissemination of socio-economic data. However, in order to carry out a count of population and acquire other demographic information, it is necessary to locate populations at a more functional, detailed level, usually by household. Data collected at household level during a census is typically aggregated to the census zone level for publication, for reasons of confidentiality and privacy, as well as to enable more realistic and manageable analysis (Curry 1999). Therefore, in countries where there is an administrative or business need for large-scale data, other spatial units are employed. Addressing, either as street encoding or postal code zones, and land parcels or property identifiers, are common mechanisms. The choice and use of a
basic spatial unit is not necessarily an objective exercise. Tradition and culture play an important role. In countries with a long tradition of public land recording and registration, such as Australia, the basic spatial unit is typically the land parcel. In countries with less of a cadastral tradition, such as the UK and USA, units based on street addresses (post and zip codes) are favoured. In either case, the issue centres on identifying and agreeing on a spatial unit of appropriate size to satisfy data the requirements (currency, resolution, and privacy) of the majority of users. This said, the reality in many cases is that a spatial unit has been conceived and developed by one agency for a specific use and then adopted by others as a de facto standard. The land parcel is a good example of this. However, a participatory and consultative approach to standards implementation is the preferred methodology and one which is indeed part of many strategies to build geographical and spatial data infrastructures (Young-Haines and Watkins 1996; Dale and McLaren 1999).

Studies of GIS in local and central government applications have shown that the most used and/or requested spatial data sets are boundary data (census, postcodes, administrative), transportation networks, water features, land parcels and elevation data (Frank, Goodchild et al. 1996). Studies of this kind are valuable and necessary to build multi-user information systems that are based on common ideals and goals and are made possible by agreed standards. They also help to break down the most significant obstacles to successful GIS projects – institutional barriers, inter-agency conflict and lack of co-ordination (Croswell 1991). Despite the advantages of performing a 'textbook' approach to systems design, through methodically documenting and analysing needs, costs and benefits in a participatory manner (the managerial rationalism approach), there are numerous cases where large infrastructural GIS and spatial data projects have evolved from other initiatives through less formal processes. Three scenarios can be identified. The first is where national land information system projects have grown and expanded to include a wider remit with divergent data (Crouse 1993). The second is where national mapping organisations who have developed a range of digital products are moving to consolidate their position as the country's main spatial data provider (Salge 1999). The third case is a combination of the two - national LIS and national mapping - becoming more integrated, both in terms of data content and institutional constituents (Williamson, Chan et al. 1995).

Perhaps of greater significance than systems design and institutional evolution is the impact of the need to establish a business case for investment. The justification for many enterprise
GIS projects, such as national land information systems, is to improve efficiency and effectiveness, i.e. to save money, and to improve service without increasing staff. The difficulty of undertaking a formal cost-benefit analysis of GIS projects is well recognised because of the problem in assigning economic value to the wide range of intangible benefits that are associated with GIS (Huxhold and Levinsohn 1995). The traditional cost/benefit approach is seen as unsuitable for valuing data and its management at the national level, and a cost effectiveness analysis is seen as a more appropriate approach.

Base upon alternative measures of value, the following benefits can be arguably justified from SDI development (ANZLIC 1996; Rhind 1996; FGDC 1999):

- the availability of fundamental data sets, enables the full potential of geo-spatial information to be realised
- the recognition that spatial data is a national resource
- the realisation of common standards for efficient data collection, storage, distribution and use
- the development of a consultative framework with the geographic information user community
- a reduction in costs through removal of duplication in data collection
- consistent cross-jurisdictional decision making
- improved customer satisfaction through the development of quality data sets
- more timely and efficient development of applications because data sets already exist
- access to resources, information and knowledge
- reduction in developmental effort by using framework data standards, standardised data, guidelines and tools
- removal of problems created by conflicting data.

This list highlights a mix of real and less tangible benefits that may be measured either directly by formal cost benefit analysis or indirectly by calculating added value or cost effectiveness, but perhaps more importantly, it suggests a move away from introspective to more holistic thinking about the value of geo-spatial information and the role of spatial data infrastructures.
2.4.5 Using the SDI model

In the context of this study, SDI provides a model from which a structure for the use and access of urban spatial data in Suva can be developed. The underlying concepts of institutional framework, technical standards, fundamental datasets, and data clearinghouses can be scaled to suit a particular data environment or application. While the obvious aim of SDI is to create national and even regional systems, the principles can be applied to specific applications and datasets.

This brief overview of SDI has highlighted a range of different influences and perspectives - data, technology, institutions, markets and applications - that are moulding the development of SDI around the world. This is clearly from the fundamental data sets of the SDIs of the developed countries examined. For example, the market driven perspective is clearly evident in the UK NGDF where the definition of core data is orientated towards socio-economic applications. An application driven perspective is illustrated by the case of the regional Asia Pacific SDI which is focussed upon environmental issues. The institutional perspective is also influential. The organisational context impacts upon the vision and scope of national SDI and this can be seen by the inclusion of thematic amongst generic data sets in a definition of core or fundamental data. There is also strong thread of land administration running through many national SDIs. This is not surprising given the institutional context for most SDI initiatives, coming from cadastral and/or national mapping organisation beginnings.

2.5 Summary

This chapter has reviewed a number of aspects relating to the applications of GIS in urban environments. The aim of this study is to develop a system that would enable and enhance the use of GIS for applications in the urban environment of Suva. The city of Suva and its surrounding hinterland is a complex and dynamic environment, and a microcosm of many of the challenges facing urban development in the Pacific region. One of these challenges is the effective utilisation of geo-spatial data and tools to enhance the management and planning activities that are necessary for the sustainable growth of the area.

Developed countries have a relatively long history of using GIS in urban applications (among many others). The large volumes of high quality data, and the demand for improved urban services have spurred development of a range of applications of GIS. Land Information
Systems have dramatically improved the efficiency with which land information is processed, and simulation and visualisation modelling are transforming the manner in which planning and management decisions are made. In the Pacific, GIS is comparatively new, and is still in the stage of creating the digital spatial data necessary for these applications to be developed. In Fiji, much of this data has already been developed, but it is not being used as extensively as the literature suggests it might be.

The next chapter will review the trends and current status of GIS activity in Fiji, as it relates to urban applications of GIS in general, and in Suva in particular. This will attempt to understand why the extensive digital spatial data already collected is not being used in the manner the literature suggests would be useful. A number of reasons could explain this. A lack of technical skill, the quality of the data and the capability of the technology available are reasons that have been traditionally used to explain the effectiveness (or lack of) GIS use. These explanations have tended to take a technical view of the reasons for shortcomings in GIS use. What is becoming increasingly apparent is a realisation that equally important are the institutional and social aspects of the way GIS is implemented and used. In complex environments like urban areas, effective use of GIS requires a high level of interaction and cooperation between different organisations with varying goals and mandates. This chapter has reviewed some of the main issues in GIS diffusion and implementation research, setting the framework for this study to compare the institutional context of urban GIS in Suva with trends observed elsewhere.

In response to the technical and institutional problems of GIS implementation, the model of SDI is becoming increasingly used to standardise data and codify institutional interactions to promote more effective and efficient use of GIS. While the ultimate goals of SDI are to build national, regional and even global systems, the underlying conceptual framework can theoretically be used to achieve the same goals of effective and efficient GIS in local environments. The results of this study, presented in the next chapter, will propose a SDI for urban GIS in Suva, based on these underlying principles and on the investigation in to the trends and current status of GIS in Suva.
3 Research approach

This chapter will explain the research approach taken in this study. Qualitative studies in geography have a long and established history. The use of information systems (IS), spatial statistics and GIS were an integral part of the quantitative revolution in geography. The recognition of the limitations of quantitative techniques in presenting a holistic picture of geographical phenomena led to the development of more qualitative approaches, based on methodology from other disciplines in the social sciences. This qualitative turn has also occurred to a limited extent in IS, and in GIS, with research now turning towards various aspects of human interaction with the technology. It is this human-technology interaction that is an important aspect of this study, and it is in this context that a research methodology is developed.

3.1 Qualitative studies in geography

The use of qualitative methods in human geography is usually traced back to the reaction against quantitative methods and the prevalence of spatial statistics in geography up to the late 1960s. The reaction to the positivist spatial science stemmed from a realisation that the study of spatial relationships was an incomplete and unsatisfactory view of the discipline, telling only part of a complex story. It became increasingly recognised that the types of phenomena being studied and modelled with these quantitative techniques, were able to measure and test only a small number of variables in the overall context of the phenomena being investigated. For example, quantitative financial, demographic and spatial variables tested in relation to the location of shopping centres are easily superseded by the forces that shape urban morphology. These larger forces, generated be decisions made by institutions such as banks, property developers and governments, are frequently not amenable to quantitative analysis dependent on large samples standard statistical tests. Similarly, it is possible to argue that political influence on spatial distribution is manifest, but the exercise of politics via power and influence, conflict and compromise is also not suitable to for analysis using the positivist scientific method (Robinson 1998).

Qualitative techniques have formed a central part of geographical investigation that have broadened the focus of research away from the spatial science agenda of the 1960s. The increased use of these techniques by geographers has reflected the emergence of a recognition of the importance and complexity of human interactions, over the more
quantitative aspects modelled through spatial statistics. Therefore, there has been a shift in
methodological approaches towards qualitative and interpretative techniques traditionally
associated with anthropology and sociology. These qualitative and interpretative methods
generally operate on the basis that the phenomena being studied is seen, conceived of and
understood in different ways be different groups and individuals (Silverman 1993). These
qualitative techniques are essentially descriptions of people's representations and
constructions of what is occurring in their world. These descriptions can take several forms
depending on the subject being researched.

Qualitative methods are best used for problems requiring depth of insight and understanding,
especially when dealing with explanatory concepts. These methods can involve all or some
of the following approaches (Hakim 1987):
- taking the perspective of the subject
- describing the detail of a setting from the perspective of participants
- understanding the actions and means in their social context
- emphasising time and process
- favouring open and relatively unstructured research designs
- an approach in which the formulation and testing of concepts and theories proceeds in
  conjunction with data collection.

Another way of viewing the characteristics of qualitative based research is that it exhibits the
following (Robinson 1998):
- a preference for naturally occurring data and field research i.e. non-experimental
- a preference for meaning rather than behaviour, and for an individual's own interpretation
  of events
- a rejection of natural science as a model
- a preference for inductive, hypothesis-generating research, which requires strong theory if
  generalisations are to be made
- a need for reflexivity in which the researcher is aware of themselves in juxtaposition to
  the subject of inquiry, implying a continual interrogation of self and subject

While these points describe the general characteristics of qualitative research, they are based
on a number of underlying research paradigms. The positivist, imperative and critical
approaches to research have been extensively documented, and are briefly described here in the context of how they can be used in qualitative investigations in information technology.

Positivist research generally assumes that reality is objectively given and can be described by measurable properties, which are independent of the observer and their instruments. Positivist studies generally attempt to test theory, in an attempt to increase the predictive understanding of phenomena. In line with this IS research can be classified as positivist if there is evidence of formal propositions, quantifiable measures of variables, hypothesis testing, and the drawing of inferences about a phenomenon from the sample to a stated population (Orlikowski and Baroudi 1991).

Interpretive research begins with the assumption that access to reality is only through social constructions such as language, consciousness and shared meanings. The philosophical base of interpretive research is hermeneutics and phenomenology (Bolland 1985). Interpretive studies generally attempt to understand phenomena through the meanings that people assign to them and interpretive methods of research in IS are aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by this context (Walsham 1993). Interpretive research does not predefine dependent and independent variables, but focuses on the full complexity of human sense making as the situation emerges (Kaplan and Maxwell 1994).

Critical researchers assume that social reality is historically constituted and that it is produced and reproduced by people. Although people can consciously act to change their social and economic circumstances, critical researchers recognize that their ability to do so is constrained by various forms of social, cultural and political domination. The main task of critical research is seen as being one of social critique, whereby the restrictive and alienating conditions of the status quo are brought to light. Critical research focuses on the oppositions, conflicts and contradictions in contemporary society, and seeks to eliminate the causes of alienation and domination (Ngwenyama 1991; Lyytinen 1992).

In much the same way as geography experienced a qualitative reaction towards the perceived shortcomings of the increasing use of quantitative techniques, IS, and by extension GIS, is experiencing a somewhat parallel reaction. While much of the research and development
work in IS continues to be technical and quantitative, there is a growing theme of qualitative research looking at the various human aspects of IT.

3.2 Qualitative studies in information technology

The study of the implementation and diffusion of IT is increasingly being undertaken from a qualitative perspective. This has allowed researchers to gain insight into some of the more subjective influences on the process of IS implementation and diffusion. Studies have shown that it is often these subjective, personal factors that are fundamentally important in the success or failure of many IS implementations, and has influenced the rate and process of IS diffusion (Campbell and Masser 1995).

The use of qualitative research methods in IT is a relatively recent development. It can be considered to be axiomatic in the sense that IT has traditionally been associated with the quantitative approach to research. IS has given quantitative researchers a powerful set of statistical tools, and has been one of the foundations of the quantitative revolution in geography. GIS, considered here as a subset of IS, is the spatial extension of this quantitative toolset. It has given an added dimension to quantitative geography, extending the power of data collection and management techniques, and giving geographers new insight into the spatial properties of the subjects under investigation.

Just as there are various philosophical perspectives that can inform qualitative research, so there are various qualitative research methods. A research method is a strategy of inquiry which moves from the underlying philosophical assumptions to research design and data collection. The choice of research method influences the way in which the researcher collects data. Specific research methods also imply different skills, assumptions and research practices. The four research methods that will be discussed here are action research, case study research, ethnography and grounded theory.

There are numerous definitions of action research, however one of the most widely cited is that of Rapoport's, who defines action research as “... research (that) aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework” (Rapoport 1970). This definition draws attention to the collaborative aspect of action research and to possible ethical dilemmas that arise from its use. It also makes clear that
action research is concerned to enlarge the stock of knowledge of the social science community. It is this aspect of action research that distinguishes it from applied social science, where the goal is simply to apply social scientific knowledge but not to add to the body of knowledge (Baskerville and Wood-Harper 1998).

The term ‘case study’ has multiple meanings. It can be used to describe a unit of analysis (e.g. a case study of a particular organisation) or to describe a research method. The discussion here concerns the use of the case study as a research method. Case study research is the most common qualitative method used in information systems (Orlikowski and Baroudi 1991). Although there are numerous definitions, Yin (1994) defines the scope of a case study as "... an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin 1994). Clearly, the case study research method is particularly well suited to IS research, since the object of the discipline is the study of information systems in organizations, and interest has shifted to organizational rather than technical issues (Benbasat, Goldstein et al. 1987).

Ethnographic research comes from the discipline of social and cultural anthropology where an ethnographer is required to spend a significant amount of time in the field. Ethnographers immerse themselves in the lives of the people they study and seek to place the phenomena studied in their social and cultural context. Ethnography is now becoming more widely used in the study of information systems in organizations, from the study of the development of information systems to the study of aspects of IT management (Harvey 1997). Ethnography has also been discussed as a method whereby multiple perspectives can be incorporated in systems and as a general approach to the wide range of possible studies relating to the investigation of information systems (Prasad 1997).

Grounded theory is a research method that seeks to develop theory that is grounded in data systematically gathered and analysed. It is an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the account in empirical observations or data (Martin and Turner 1986). The major difference between grounded theory and other methods is its specific approach to theory development - grounded theory suggests that there should be a continuous interplay between data collection and analysis. Grounded theory approaches are becoming
increasingly common in the IS research literature because the method is extremely useful in
developing context-based, process-oriented descriptions and explanations of the phenomenon
(Pettigrew 1985).

In consideration of these various methodological approaches to qualitative studies in IS, a
combination of action research and case study methods has been chosen for this study. As
has been described in the introduction, the aims of this study are; firstly, to evaluate the use
of GIS from an organisational viewpoint; secondly, to acquire data and test its usability for
urban GIS applications; and thirdly to use the information gained to propose an integrated
urban GIS based on the principles of SDI. To achieve the first aim, a case study approach
was used, to evaluate the status and trends of GIS within the organisations identified. The
second aim was achieved using an action research approach, where the organisations
contributed to various degrees in the process of acquiring and analysing data. Lastly, the
third aim was achieved by reviewing structure and status of a variety of SDI together with the
knowledge obtained from the organisational survey, and proposing an urban SDI based on
SDI principles and local GIS environment.

3.3 Design of research techniques

The characteristics of qualitative research require a set of techniques that enable the
researcher to address the issues under investigation, and usually have a much less structured
form than quantitative, statistical approaches. A number of broad categories of techniques
have emerged; questionnaire surveys, informal surveys, participant observation and
document interpretation. The exact technique and form used depends on the factors such as
the subject under investigation, the results of preliminary surveys, the accessibility of
documentation and the intuition and experience of the researcher.

The methods chosen for the organisational case studies were a combination of questionnaire
survey, to establish baseline data about GIS and IT in the organisation, and focused
interviews with key individuals.

In order to survey the history and role of GIS within the organisations, a series of interviews
were conducted with a person within the organisation who it was determined (through
observation and informal, exploratory discussion) would have the best knowledge of the GIS,
its history and its use and role in the organisation. These interviews took the form of
structured questions, common to all the respondents, followed by unstructured questions, and a general discussion to expand and elaborate on some of the aspects of the study unique to that organisation. In some cases it was necessary to interview a number of different people within the organisation, as there was no one individual who was able to give satisfactory answers to all the questions. A second reason for interviewing a range of people within the organisations was to attempt to get a variety of perspectives on the GIS, especially in terms of its role and effect on workflows and productivity in the organisation. As has been discussed in the literature review, the actual effectiveness and perception of GIS within an organisation is often different from that which is officially described by managers and supervisors. A further reason for conducting the survey in the form of in-depth interviews is that much of the information regarding the implementation of GIS is not documented in any form. This is typical of situations in which IS in general are implemented on an ad hoc basis. While there is sometimes documentation regarding proposals to implement GIS, there is virtually nothing documenting the process by which the system was implemented and a critical evaluation of its effectiveness in terms of the original proposal. This is especially true in some of the smaller organisations, where a GIS is set up by an individual for a specific project, and then is gradually absorbed by others and becomes more widely used. A final point on the topic of documentation is that much of the documentation that does exist is confidential, especially in the case of private companies. This makes it difficult to trace formal developments in the implementation and use of GIS.

Once the organisational surveys were completed, the next step was to create sample applications of GIS using spatial and attribute data from the organisations. This was achieved by firstly gaining management support for the study by explaining some of the potential uses of integrated GIS. Once this support was gained, a key individual within the organisation was identified who would be able to provide access to the organisation's data. This data was then collected and integrated using a variety of software tools and methods, to produce sample applications of integrated urban GIS, along the lines of those identified in the literature review.

This hands-on access and manipulation of the data allowed for a better insight into the technical aspects of the data and applications. This in turn contributed to the discussion on SDI, and the potential for SDI to act as a framework for integrated urban GIS.
3.4 Statement of research hypothesis

The literature in relation to GIS implementation suggests that the success of GIS implementation is a complex function of inter-related variables. Primarily, it is a function of the efficiency of the existing information infrastructure, and the ability of the organisation to manage the flow of information within the organisation. A secondary variable is the nature of the spatial data that is not usually handled as part of the normal IT data flow in an organisation.

The aim of the study, as explained in the introduction, is to develop the principles for creating and managing an integrated GIS for Suva. This will be done by investigating the process of GIS development in various organisations, with particular emphasis on those organisations working in the field of urban management and planning. The first hypothesis of the study relates to the process of GIS development in Fiji, and is stated as follows:

The process of GIS development in organisations in Fiji is a function of the efficiency of the existing information infrastructure and the level of awareness of, and support for, GIS within the organisation.

The second hypothesis of the study deals with the integration of information between organisations. As the aim of the study implies, the concept of an integrated urban land management system depends on integration of data and information between organisations working in the field of urban land management. The second hypothesis is stated as follows.

The use of GIS for urban applications in Fiji can be enhanced through the use of a SDI-based method for data integration.

The first hypothesis will be tested using a series of targeted interviews and literature research. The second hypothesis will be tested by creating a framework for an urban SDI, and applying this framework to various urban applications of GIS.

3.5 Questionnaire survey

A baseline questionnaire was administered to each of the organisations identified. This baseline questionnaire was designed to gather data on three main areas. The first part of the
questionnaire contained questions designed to gather data about the current GIS implementation within the organisation. The second part of the questionnaire dealt with the structure of IT within the organisation, and the relationship between GIS and IT in the organisation. The third part of the questionnaire dealt with the process of sharing data and information between the organisation under review, the other organisations targeted in the survey, and other organisations and institutions not covered in the survey.

This baseline questionnaire was in the form of specific, targeted questions to establish baseline, quantitative data concerning factors such as data collection, software used, organisational structure, flows of data and information within the organisation and exchange of data and information with other organisations. This was followed by open-ended questions, designed to facilitate a discussion about the organisation and the role of GIS and IT within the organisation, and to attempt to identify some of the factors determining the effectiveness of the GIS.

3.6 Focused interview

The second part of the study involved focused interviews with key individuals identified in the questionnaire survey, and through a personal knowledge of the state of GIS and some of the individuals involved in the important developments of GIS in Fiji. These focused interviews were in the form of open-ended discussion, centred on the key points raised in the baseline questionnaire survey. These interviews were used, not only to gain more detailed information about the use of GIS, and its technical aspects, but also to investigate the perceptions of GIS by various people within the organisation.
4 Results

This chapter presents the results of the study in two main sections. The first section summarises the results of the questionnaire surveys and focused interviews conducted to assess the nature and role of GIS within the organisations surveyed and the implementation path of the GIS. These results are presented in two parts. The first part is an organisation-by-organisation summary of the GIS structure and role within each organisation, acquired through the questionnaire survey. The second part focuses on the issues raised in the surveys, and describes the results of the focused interviews in the context of the aims of the GIS and the implementation path.

The second section of these results describes the data integration and visualisation process, where data was acquired from the various organisations, and merged using GIS tools. These data layers were then used to produce a number of visualisation models, and critiqued as to their applicability for integrated urban planning and management.

4.1 Organisational summary of GIS in Fiji

A comprehensive overview of the state of GIS in Fiji is of fundamental importance in any attempt to develop an inter-organisational approach to an integrated urban information system. GIS in Fiji is a relatively recent development, with the first true GIS being first set up in the early 1990s. Since then, a growing number of organisations and institutions have developed, or attempted to develop some form of GIS or spatial data handling system.

This section reviews a number of GIS implementations from an organisational perspective. For each organisation and institution, the history and role of GIS in the organisation will be summarised, followed by comments and observations on the characteristics of the GIS operations within the organisation and its links with the GIS community in the country.

4.1.1 Department of Lands and Surveys

The Department of Lands and Surveys (DLS) is the government department primarily concerned with collection, storage and management of spatial data. The department is divided into three main sections: Valuations and Legal, Mapping and Land Information, and Surveys. Each of the three sections handles different aspects of spatial data, in a variety of forms for a variety of functions. The information presented here is a summary of a series of
interviews and discussions held with the following staff of the DLS; Kemueli Masikerei, Manager of the FLISSC; Rashmi Rita, Project Officer; and Mark Williams, Senior Technical Officer.

The Valuations and Legal section deals with the valuation and legal aspects of land administration that fall within the state's jurisdiction. A number of attribute databases are administered within the section, mainly the valuation of registered properties, and the valuation of state and native land leases.

The Mapping and Land Information section is divided into a number of units. The mapping unit is responsible for the creation of hard copy and digital spatial data, and is the home of the Fiji Land Information System (see below) (Masikerei 2001). There are three main types of map data handled by the department, namely state and freehold land boundaries and attributes, topographic layers, and native land boundaries and attributes. The first two (state and freehold, and topographic) are entirely administered by the Lands and Surveys department. The third (native land) is developed and administered jointly with the Native Lands and Fisheries Commission.

Figure 4-1. Organisational layout of Department of Lands and Surveys.
State and freehold land boundaries are mapped and managed through a complex system of flows of data with the Department. When changes to land boundaries within the state and freehold land system are made, these changes are first approved by the Department of Town and Country Planning (Singh 2001). Once this approval is granted, the survey plans of the new boundaries are submitted to the Drafting section, where they are checked for compliance with surveying regulations. Once this approval is granted, the plans are passed to the Graphics section, where they are digitised and the amendments made to the digital cadastral base. Once the cadastral base has been amended, the plans are passed to the Drafting section, where they are stored. The Drafting section stores both the Traverse Plan\(^2\) and Title Plan\(^3\) for all state owned land. In the case of freehold land, the Traverse Plan is stored with the Records unit, and Title Plan is passed to the Titles Office. The Titles Office is the government department responsible for the storage and management of all land titles, and is located within the Ministry of Justice (Williams 2001).

Topographic data is the second main spatial data component developed and managed entirely by the Department. Topographic data is generated by the Air Survey Unit, based on stereo mapping from aerial photographs. Most of the land area of Fiji is covered by 1:50,000 scale topographic maps sheets, developed from aerial surveys flown in the 1960s and 1970s, and updated by new, partial surveys in the early 1990s. The base topographic layers are captured at 1:25,000 scale, from where they are transferred to the Graphics Unit, where they are annotated and printed at 1:50,000 scale. The Graphics Unit also converts the topographic sheets to digital form, through a combination of manual digitising and scanning and vectorising.

As described earlier, the administration of native land is jointly managed by the Department of Lands and Surveys, and the Native Lands and Fisheries Commission (NLFC) through the Native Lands Trust Board (NLTB). The NLFC is responsible for the delineation of traditional land owning boundaries. The NLTB is responsible for the development and use of native land, which takes the form of administering the leasing, subdivision, and land development of native land on behalf of the traditional land owners. The traditional land

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\(^2\) A schematic plan showing the survey marks and distances and bearings of all boundaries in the area.

\(^3\) Similar to the Traverse plan, but containing descriptive information about the boundaries such as lot numbers.
ownership boundaries were originally mapped in the early part of this century as part of the colonial administration’s national mapping programmes. The NLFC has developed a digital mapping system to capture and store these traditional boundaries (Rita 2001).

The Survey section is responsible for the development and maintenance of the geodetic control network. The geodetic control network is the national network of geodetic control points, surveyed to a high level of accuracy, from which individual land surveys must be based. The geodetic control network forms the base for all land surveying in the country, and work is continually under way to improve the accuracy and extent of this network. The Survey section is also responsible for surveying all state owned and leased land, and entering these survey plans in to the national cadastral base (Masikerei 2001).

### 4.1.1.1 The Fiji Land Information System

The Fiji Land Information Systems (FLIS) is the largest GIS in the country, and is the principle digital data management system within the Department of Lands and Surveys. It was set up in the 1992 to coordinate the creation of a digital land information system for Fiji. The centre was set up under a New Zealand government aid funded project to create a national land information system that would eventually include a wide variety of linked spatial databases. The FLIS comes under the jurisdiction of a umbrella organisation called the Fiji Land Information Council (FLIC), formed in 1991. The FLIC is made up of representatives from a variety of government departments, statutory bodies and private organisations, with a mandate to oversee policy and management of the FLIS. The FLIS is implemented and maintained by the FLIS Support Centre (FLISSC), which exists within the Mapping and Land Information Section of the DLS. The role of the FLISSC is to coordinate and develop the various digital databases that make up the FLIS.

In total, the FLIS is made up of a total of 22 separate databases that contain both spatial and non-spatial data and attributes. These are summarised below.
Table 4-1. The FLIS databases.

<table>
<thead>
<tr>
<th>No.</th>
<th>System</th>
<th>Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Computerised Cadastral Mapping System (CCMS)</td>
<td>The GIS database that holds the spatial representation of all cadastral boundaries</td>
<td>Department of Lands and Surveys (DLS)</td>
</tr>
<tr>
<td>2</td>
<td>Titles Journal</td>
<td>A system that captures the details and movement of documents through the Registrar of Titles' office</td>
<td>Registrar of Titles</td>
</tr>
<tr>
<td>3</td>
<td>Titles Index</td>
<td>Contains key information for all Certificates of Titles, Crown Leases, Native Leases, Crown Grants, Native Grants and sub-lease</td>
<td>Registrar of Titles</td>
</tr>
<tr>
<td>4</td>
<td>Survey Plan Journal</td>
<td>Holds details of every survey plan, and tracks those plans through the approval process</td>
<td>DLS, Systems Support Unit</td>
</tr>
<tr>
<td>5</td>
<td>Survey Plan Index</td>
<td>Contains key information for all approved survey plans.</td>
<td>DLS Systems Support Unit</td>
</tr>
<tr>
<td>6</td>
<td>Valuation Records</td>
<td>Holds all valuation assessments made by the DLS, as well as details of property sales.</td>
<td>DLS Legal Section</td>
</tr>
<tr>
<td>7</td>
<td>Road Index</td>
<td>Textual details of all legal roads in Fiji</td>
<td>DLS Systems Support Unit</td>
</tr>
<tr>
<td>8</td>
<td>State Lease Administration</td>
<td>Contains details of all registered and unregistered state leases</td>
<td>DLS Systems Support Unit</td>
</tr>
<tr>
<td>9</td>
<td>State Rental System</td>
<td>Contains rental details of all state leases and native leases to state</td>
<td>ITC</td>
</tr>
<tr>
<td>10</td>
<td>State Land Register</td>
<td>An inventory of all state land with and without title</td>
<td>DLS Legal Section</td>
</tr>
<tr>
<td>11</td>
<td>Native Land Register</td>
<td>An inventory of all native land</td>
<td>NLC</td>
</tr>
<tr>
<td>12</td>
<td>Vola Ni Kawa Bula</td>
<td>A record of all indigenous Fijians referenced to the land owning units</td>
<td>NLC</td>
</tr>
<tr>
<td>13</td>
<td>Town and Country Planning Applications</td>
<td>Holds details of all planning applications, including processing and condition.</td>
<td>DTCP</td>
</tr>
<tr>
<td>14</td>
<td>Census mapping</td>
<td>Holds records of national census boundaries 1976, 1986 and 1996</td>
<td>FLISSC</td>
</tr>
<tr>
<td>15</td>
<td>Fiji Topographic Database</td>
<td>Layered topographic data derived from 1:25,000 national mapping</td>
<td>DLS Graphics Unit</td>
</tr>
<tr>
<td>16</td>
<td>Native Land Mapping System</td>
<td>Digital representation of all boundaries recorded on NLC maps</td>
<td>DLS Graphics Unit</td>
</tr>
<tr>
<td>17</td>
<td>Geodetic database</td>
<td>A record of all survey controls in Fiji</td>
<td>DLS Survey Section</td>
</tr>
<tr>
<td>18</td>
<td>Government Rented Properties</td>
<td>An inventory of all properties rented by the state</td>
<td>DLS Systems Support Unit</td>
</tr>
<tr>
<td>19</td>
<td>Native Leases to State</td>
<td>An inventory of all registered and un-registered native leases to state</td>
<td>DLS Systems Support Unit</td>
</tr>
<tr>
<td>20</td>
<td>Vanua View</td>
<td>A viewing package for CCMS and topographic data</td>
<td>DLS Graphics section</td>
</tr>
<tr>
<td>21</td>
<td>Metadata</td>
<td>A detailed description of all FLIS digital data and products</td>
<td>FLISSC</td>
</tr>
<tr>
<td>22</td>
<td>Land Accounts Cash Flow</td>
<td>Record of cash flows within the DLS</td>
<td>DLS Legal Section</td>
</tr>
</tbody>
</table>

Source: (FLISSC 2000).

As the table above shows, the FLIS consists of a wide variety of spatial and non-spatial data and is distributed over a number of organisations and sections. Because of its size and
complexity, a number of different software are used for various parts of the system. Much of the spatial component is captured and managed by Intergraph Microstation software, with the attribute data being handled by a variety of DBMS, especially Oracle, Microsoft Access and Advanced Revelation. For the Computerised Cadastral Mapping System (CCMS) and topographical data, the spatial and attribute components are link through Microstation GIS Environment (MGE) tools (Rita 2001). All of the software runs in a Microsoft Windows environment, although not all on the same version and not all in the same network environment.

Because of its size and physical disparateness, the IT capabilities of the department are varied. Different sections of the department purchase and run their own IT systems according to their individual needs, and in consultation with the FLISSC and the government's central IT coordinator, the Information Technology and Computing (ITC) centre which, for historical reasons, comes under the jurisdiction of the Ministry of Finance. The end result of this is that the department has a range of IT systems, from standalone personal computers running word processing and spreadsheets, to server-based networks. There is also a range of system support, in the form of a combination of in-house IT specialists and private contractors, engaged in conjunction with hardware and software purchase service agreements, or on an as-needs basis (Williams 2001).

4.1.1.2 Vanua View

Vanua View is the major digital data product being marketed by the FLISSC. It consists of a series of layers generated from the CCMS and topographic bases, and packaged in a viewable format.
Various layers can be selected and overlaid, and a basic query tool allows for text string searches of the cadastral label layer.

The data is in a proprietary binary format, meaning that it cannot be extracted or exported for use in other GIS and mapping software. The aim of Vanua View is to provide a simple interface for basic map production and query.

### 4.1.2 Department of Town and Country Planning

The Department of Town and Country Planning (DTCP) is a government department within the Ministry of Local Government, Housing and Environment. The department has two main operational sections. The Sub-division of Land Sections deals with applications and permits for land subdivision and re-zoning. The Development Control Section handles all building
and construction applications and permits and oversees all building and construction work to ensure these are carried out in compliance with approved plans and procedures. Above these two sections is the Director’s office, which deals with the process of forward planning of land allocation on a regional scale. The information presented here is a summary of a series of interviews and discussions held with the following staff of the DTCP; Ravendra Singh, Senior Technical Officer, and Josephine Narayan, Research Officer.

Because of staffing problems and the lack of an overall land use strategy, a large percentage of land development takes place in an ad-hoc fashion, with individual land development proposal being assessed and implemented on a case by case basis, without reference to a local or regional land use strategy. This is especially true in the case of the Lami-Suva-Nasinu-Nausori area. The last planning document for this significant urban conurbation was published by the Department in 1975 (DTCP 1975). Work is currently under way to revise and update this document, but due to a variety of factors (political as well as operational), this has not been possible, and there are no indications as to when this document will be published (Singh 2001).

Like many other government departments, the implementation of IT in the Department of Town and Country Planning has not occurred as part of an overall IT strategy. The current use of IT in the department is limited to the use of word processing and spreadsheets on a piecemeal basis by staff. Almost all the data handled by the operational sections of the department is in paper format. All applications for permits are submitted on paper forms with hard copy documentation attached. These often include maps and plan drawings of the areas under consideration for rezoning or sub-division permits. This documentation is then processed by the staff of the department, who assess applications based on various criteria and may make visits to the site and carry out local surveys and research to help in the process of evaluating the application. The decision making process involved in assessing these applications is beyond the scope of this study (Narayan 2001).

Once permission is granted for re-zoning and sub-dividing, these changes are then forwarded to the Department of Lands and Surveys for incorporation in their system. The survey section within the department will survey the subdivision as necessary and update the cadastral record together with any changes to zone. These will then be mapped by the drafting section, which will also update the digital record through the CCMS.
At present, the most significant use of GIS within the department is in the use of the VanuaView package, distributed by the FLIS Support Centre. The main use of the software is to produce town planning schemes, maps of the various zones within the municipal boundary areas (Narayan 2001). Because VanuaView is simply a viewing package, and has no mapping capability other than printing boundaries and labels, zone maps are produced by printing out a series of sheets showing the cadastral boundaries, manually edge-matching them, and then hand-colouring the zones.

4.1.3 Suva City Council

The Suva City Council (SCC) is the second largest municipal council in the country, after the incorporation of Nasinu as a city in 2000. The main activities of the council, similar to the activities of any large municipal government, are in the provision of local services to the areas covered under the city’s jurisdiction. Many of these services involve the use of geographically referenced information, but the implementation of GIS in the council has had a number of problems over the years. The information presented here is a summary of a series of interviews and discussions held with the following staff of the SCC; Kala Wati, GIS Project Officer, Asenaca Nawaqalevu, City Planner and Eric Singh, Project Engineer.

The main operations of the council include processing of re-zoning, subdivision and building applications in conjunction with the Department of Town and Country Planning, the issuing and checking of business licenses, the collection of solid waste, and the maintenance of roads and public areas within the city boundaries. The council is funded through the collection of city rates, and through central government grants through the ministry of local government, housing and environment (Nawaqalevu 2001).

Like many of the other organisations described in this section, the council has implemented IT solutions in an ad-hoc manner, with no overall information strategic plan. In this environment, the implementation of any kind of solution GIS is burdened with the problems of a poorly defined IT structure. A number of efforts to develop GIS within the council have not succeeded for a variety of reasons.

The current IT implementation within the council is in the form of an external contract awarded to a local IT provider. Under this contract, hardware and software is provided to the
council in the form of a turnkey solution. The software provided consists of suite of office automation tools, and a custom built financial tracking programme for the handling of the council’s finances. Part of this programme includes a number of spatially referenced data sets, centred on property descriptions in the form of lot and plan codes, and an index based on the valuation data of the property. The council also has a number of other computers and software purchased separately from the IT contract, on which some of the data is backed up and used for other purposes (Singh 2001).

The first attempt at setting up a GIS was under a project undertaken under a funding programme from the French government. Under this project, hardware and software were purchased and two French consultants were appointed to undertake a digital mapping project to capture property boundaries within the council’s jurisdiction. The project had a timeframe of one year, and apparently succeeded in create a digital coverage of the property boundaries, but was unable to link this to any attribute data (Wati 2001). Since then, the hardware used has been taken over by other staff and used for non-GIS activities. During the timeframe of the project, only one local staff member was included in its activities and given training in the workflow of the project. Unfortunately, this staff member left the council soon after the end of the project, resulting in no one remaining who knew anything about the project or how to use the data (Nawaqalevu 2001).

In 2000, as part of its education and outreach programme, the FLIS support centre provided data and software training to a number of municipal councils, including the Suva City Council. Since then, a staff member of the council has been given responsibility for GIS, and has succeeded in creating a town planning scheme for Suva, based on the zone for each property within the city boundary. This has been a largely manual process, of checking hard copy files of each property and assigning the appropriate attribute to that property within the GIS software. The primary output of this data has been in the form of printed maps used in council reports and other documents (Nawaqalevu 2001).

### 4.1.4 Bureau of Statistics

The Bureau of Statistics (BS) has the largest collection of socio-economic statistical data in the country. This data is derived from a wide variety of data collection projects, and is regularly published in a series of reports and monographs. Following the 1996 census, a GIS section was set up within the Bureau to produce population maps from the extensive data
gathered during the census. The information presented here is a summary of a series of interviews and discussions held with the GIS Project Officers, Turenga Nakalevu, and Inia Saula.

A number of problems have been encountered in the implementation of the GIS, both technical and institutional. Early on in the project, much time was spent in the process of manually creating polygons of the enumeration areas defined in the census. These areas were originally digitally mapped by the FLISSC and printed maps produced to aid in the planning of the census count. When it was decided to set up a GIS section within the Bureau of Statistics, the digital maps were given to the Bureau in the form of unclosed lines. In order to link the census data with digital maps, it was first necessary to create polygons from the unclosed lines. This process took over a year due to the large number of enumeration areas, and the limited technical expertise within the GIS section (Saula 2001). Once the polygons were created, they then had to be identified with the appropriate enumeration area code. Once the enumeration areas were polygonised, they were then linked to the extensive attribute information collected in spreadsheets from the census count, via the enumeration area code (Nakalevu 2001).

From an institutional perspective, the Bureau has a relatively restrictive data sharing procedure. This has meant that very limited use is made of the extensive data collected by the bureau. While the results of surveys and census counts are made available in hardcopy form, the Bureau imposes restrictions on the general distribution of its data in digital form, and has yet to make any of the 1996 census data available at the enumeration area level, except for small subsets of the data over a relatively small spatial extent (Nakalevu 2001).

4.1.5 Native Lands Trust Board

The Native Lands Trust Board (NLTB) is the statutory body that is responsible for the administration of all native land in Fiji. It oversees the management and use of native land on behalf of the traditional owners, and collects and distributes the rent from all land leased under its control. The role and use of native land in Fiji is a contentious topic, and beyond the scope of this study to discuss in detail. Its relevance to urban change and the process of urbanisation in Fiji is that many urban areas have expanded well beyond the original state and freehold land boundaries. In order to cater for this inevitable expansion, native land will continue to be increasingly utilised. The NLTB will become one of the most influential
players in the process of land utilisation and urbanisation in the near future. The information presented here is a summary of a series of interviews and discussions held with the following staff of the NLTB; Isoa Tamani, Senior Technical Officer, George Tami, Project Officer and Poiongo Lisati, Project Officer.

The NLTB was the first organisation in Fiji to implement a GIS, which it did in 1989. This was done in response to a need to capture in digital form all the boundaries and attributes of the native land under its jurisdiction. Before the implementation of the GIS, the NLTB had in place a mapping and cartographic department producing maps and plans of native land boundaries, leases, subdivisions and other land boundaries determined and administered by the organisation (Tamani 2001).

The original GIS in the NLTB was set up using InfoCAD, a surveying and design software, primarily for the production of hardcopy maps (Tami 2001). In the mid 1990s, MapInfo began to be used, together with a set of GPS receivers for rapid surveying of lease boundaries in remote areas (Lisati 2001). Since 1999, the NLTB has undergone significant internal restructuring, and the original GIS section has been dissolved with its various functions now undertaken by a variety of other departments with the organisation.

4.1.6 Public Works Department

The Public Works Department (PWD), under the Ministry of Infrastructure and Public Works, is the government department in charge of building and maintaining public infrastructure, in particular roads, water and sewerage systems. The PWD is one of the largest government departments working on a wide range of public infrastructure projects around the country. The majority of these projects involve the construction and upgrading of roads around the country, especially in rural areas, improving the supply and capacity of the various water supply networks, and developing and expanding the sewage collection and processing systems. The information presented here is a summary of a series of interviews and discussions held with the Anthony Toko, GIS Project Officer (Roads).

Because of its size, the department has a larger IT infrastructure than some of the other smaller organisations surveyed. The IT infrastructure is still implemented on a piecemeal basis, in response to the needs of the individual sections and units within the departments, as their need for IT solutions increases, and funding becomes available. There is no overall IT
strategic plan, resulting in the inevitable fragmentation of the IT infrastructure and duplication of various solutions (Toko 2001).

Over the last 10 years, a number of attempts have been made to implement various types of GIS, with varying degrees of success. The PWD took part in an early pilot project, in conjunction with the power telecommunication utilities, to create an integrated utilities GIS (Patterson 1997). Of these three organisations, only the telecommunications utility has adopted an extensive, enterprise GIS. Within the PWD, only the roads section has been able to implement any kind of lasting GIS solution. This has taken the form of an automated road mapping system, using a combination of GIS software, GPS receivers and digital video cameras. This system is fitted in a customised 4WD vehicle, which is then driven down the road to be surveyed. The location data is captured by the GPS receiver, and later differentially corrected for greater accuracy. Attribute data of the road, including road surface type and condition, verge and pavement condition, line markings and road signs are entered using the data captured on the digital video system (Toko 2001).

The water and sewerage section of the PWD have mapping and plan drawing capability, but there are no plans as yet to develop this into a GIS.

4.1.7 Telecom Fiji Limited

Telecom Fiji Limited (TFL) is a private company providing terrestrial telecommunications services to Fiji. The company has been in existence since 1990, when it was privatised out of a government statutory body, the Posts and Telecommunications Department. As part of this privatisation process, the two arms of the department were spun off to function as private companies. TFL is one of three major monopolies in the telecommunications sector in Fiji. Vodafone Fiji provides mobile telecommunication services, and Fiji International Telecommunications Limited provides access to international telecommunications networks. In terms of physical infrastructure, TFL has by far the largest network of the three, and it is this infrastructure that is the centre of the company’s GIS. The information presented here is a summary of a series of interviews and discussions held with the following staff of TFL; Autiko Loulou (GIS Manager); Sanele Miller (GIS Assistant Manager); and Manoa Ravutia (GIS Officer).
Telecom Fiji has the most technologically advanced GIS of all the organisations surveyed in this section. The GIS at TFL is primarily designed for asset management. The system has its roots in the mapping and drafting section on the company. As part of the privatisation process in the early 1990s, a number of technologies were adopted in an attempt to improve the efficiency of the operations of the company. One of these technologies was GIS. The initial implementation of the GIS was tendered to Intergraph NZ, who designed and set up the GIS based on the MGE suite, with Oracle as the attribute database. There is also a front-end viewer, FieldView, which is designed to give non-GIS staff the ability to view and query the data (Loulou 2001).

The GIS within TFL is primarily designed to assist in the mapping and location aspects of the companies operations. The GIS is set up around the mapping of the network infrastructure. Cables, junctions, distribution points, exchanges and other external plant were all captured from plan sheets and linked to attributes from the company’s asset database. This increased the efficiency of mapping and location finding operations. Before the implementation of a GIS, the network infrastructure was manually stored and updated on plan sheets (Miller 2001). The first step in the GIS implementation was to digitally capture these plans. This digital capture process was tendered to an offshore IT company, where the plans were sent for digitising. These digital plans were then edge-matched to create continuous layers of data (Loulou 2001). The next major step in the GIS implementation was to integrate the network infrastructure with the land base. The aim of this is to be able to locate the network infrastructure in relation to the various land ownership and administrative boundaries. The cadastral base from the DLS was used to locate property boundaries on freehold and state land.

One of the main applications for the GIS outside mapping and inventory management was the need to be able to speed up the process for locating customers. The main bottleneck in this process had been the delay in locating the applicant’s address in relation to the existing network infrastructure. This was addressed by using the cadastral base and superimposing it over the network infrastructure. A query then locates the label of the customer’s lot and plan number, from which it is then possible to view the location in relation to the existing infrastructure. If there is a free distribution point within a suitable distance of the property, the process of connecting the property to the network can begin (Ravutia 2001).
The other main application is in maintenance and repair operations. The network infrastructure is linked to the company’s Integrated Customer Management System (ICMS), which contains the customers’ account, contact details (such as postal address, alternate telephone numbers etc.) and the distribution point to which the customers’ telephone connection is made. When a fault is reported, all that is required is one attribute of the customer from the ICMS (usually the name and telephone number to confirm). From this, a maintenance form is created, listing the customers’ details, including the distribution point. The maintenance staff then connect to the GIS, and run a query to locate the distribution point on an on-screen map display, which is then printed out and used in the field to locate the distribution point and the customer (Loulou 2001).

Other applications of the GIS are currently under development. One of these is to integrate demographic data with the existing infrastructure and property layers. A pilot project is currently under way using enumeration area boundaries from the Bureau of Statistics, to assist in planning extensions of the infrastructure network (Loulou 2001).

TFL has an extensive and well managed IT infrastructure. The IT infrastructure is part of a company-wide IT strategic plan, designed to streamline the management of data within the company. Because of the mission critical nature of digital data within a telecommunications company like TFL, the use of IT is well developed. The Management Information System (MIS) section handles the sophisticated ICMS, centred on customer accounts. The information from the ICMS is made available to other sections of the organisation, such as GIS and planning, for use and integration in to their operations. The use of large amounts of digital data within the organisation, and the fact that it is primarily concerned with telecommunications, results in an extensive and efficient digital data hardware and software infrastructure.

4.1.8 Fiji Electricity Authority

The Fiji Electricity Authority (FEA) is a statutory body responsible for power generation and distribution in Fiji. Electrical power is generated at a number of sites, using a variety of hydro powered and fossil fuel powered stations. The electricity is then distributed to consumers via a power distribution grid over the two main islands and a number of smaller islands. The information presented here is a summary of an interview held with Timoci Bavadra, (Planning Manager) and Vilisi Sorovi (GIS Project Officer)
Unlike Telecom Fiji Ltd, the FEA has not implemented a significant GIS to date. In the mid 1990s, a number of small pilot projects were carried out to demonstrate the use of GIS in the power distribution industry (Bavadra 2001). These projects involve the mapping section of the organisation using GIS to improve their mapping and plan drawing capabilities. A combination of tools were used to capture the location of external assets such as power poles, transformers and sub-stations. Large scale aerial photographs, especially in urban areas, provided a backdrop over which assets were mapped. In rural areas, and in locations where appropriate aerial photography did not exist, GPS receivers were used to record locations of assets, which were then integrated with the GIS (Sorovi 2001).

While the pilot project proved successful in demonstrating some of the uses of GIS, a full adoption of the technology has yet to take place. One of the main reasons for this is the state of the privatisation process of the organisation. There have been plans in place for a number of years to split the FEA in to three separate organisations, independently responsible for power generation, power distribution and billing and customer service (Bavadra 2001). With major changes to its organisational infrastructure in the pipeline, the implementation of new technologies like GIS are not considered a priority.

4.2 Issues facing GIS development

Following this review of the history and functions of GIS in the organisations surveyed, a number of general points were raised. These points relate to issues not specific to one organisation, but to the use and perception of GIS in general. They can be broadly divided in technical issues and institutional issues.

4.2.1 Technical issues

The most prominent technical issue observed and expressed is to do with spatial data. The FLIS is seen to be the source of much of the spatial data that could be, and is being, used for a variety of GIS implementations. The native format for this data within the FLIS is Intergraph Microstation design files for the graphical component, with attributes stored in a variety of database formats, with the two linked using MGE. The conversion of this data to the format predominately used in Fiji, MapInfo table files, has been problematic. In many cases, when data has been converted, it is only the graphical component that is converted, without useful attributes from the linked database (Rita 2001).
This is illustrative of one of the main problems facing GIS development in Fiji. The focus on hard copy output has meant that the data often does not have the necessary spatial structure and attribute databases that would enable more sophisticated spatial operations and analysis that 'true' GIS is capable of. For example, the main end user product that is sold by the FLISSC is a viewing package called VanuaView. This package contains various layers of spatial data in graphical format, which can be zoomed and printed. There is a simple query tool, which allows users to query an attribute by scrolling through a text list of attributes for each layer. Each attribute is listed as a text item, followed by the geographic location of the attribute label in the graphical map window. The user selects the text attribute and the system then centres the location of that attribute on the map window, using the geographic location from the attribute list. There is no direct link between the attribute and its spatial representation. While this may be appropriate for a section of potential end users, it does not make the power of spatial data available to a more sophisticated market.

A problem associated with the extraction of data from the FLIS to MapInfo, has been in maintaining the topology of the data. Within Microstation, polygons are drawn by connecting a series of line segments together. This connectivity is recognised by the software and the necessary topology generated on the fly. In the conversion process to MapInfo, the lines are often converted as lines, and not as polygons, meaning that the topology is not maintained, and the areas appear in MapInfo as unconnected lines.

In the topographic layers, the same problems are also apparent. In the conversion process from the paper map sheets, the topographic features are converted as graphical objects, with unconnected lines and little valid topology. Attributes are not linked to the graphic objects, but are converted to a layer of labels, which can be viewed on top of a particular topographic layer. The graphical objects themselves have no attributes.

While these issues relate to the graphical component of the data, the non-spatial attributes present a different set of problems. Of particular note here is the variety of methods used to identify different land parcels in various organisations (Williams 2001). There is no unique, standard land identification system across the organisations surveyed. In theory, each parcel of registered land can be traced to an original survey plan (which is uniquely identified), on which the individual parcel is identified with a lot number. All registered parcels are issued
with a certificate of title, describing the location and extent of the parcel with reference to the plan and lot number. These parcels are typically graphically identified in the FLIS by a text label on a map sheet or digital layer.

Ideally, this text label becomes the standard identifier for the parcel, but the reality is that the label is often misused, altered and even ignored. Because of this lack of standardisation, various organisations maintain a separate index of parcels, with one part of this index containing a text reference to the parcel label. As the example below, from the SCC valuation index shows, the property is identified with a complex text string containing a combination of title, lot and plan number, street address and parcel dimensions ('FR' stands for frontage) (Wati 2001).

![Figure 4-4. Valuation index showing non-standard property identification data.](image)

The Legal Description column shows various parts of the property identification, including street address, title number, and lot and plan number. In each case, this information is presented in a different format, with little consistency in structure.

The problems of lack of consistency in graphical topology and the arbitrary use of parcel identifiers are the most important technical constraints facing improved use of GIS. These
problems stem from the underlying use of GIS for map display output, both on-screen and on paper. The arbitrary use of parcel identification numbers appear to stem from the independence of the various databases. There is virtually no linkage between the different databases, resulting in a lack of common identifiers. This problem will be discussed further in the next section on institutional issues.

4.2.2 Institutional issues

The institutional issues facing GIS development encountered in the context of this study are classified into 3 main areas. The first area is concerned with the implementation of the GIS within the organisation. This is characterised by the role of GIS within the organisation, which is often located as a separate unit on the periphery of the data and operational environment of the organisation. The second set of institutional issues is concerned with the relationships between organisations, and in particular the flows of data and information between organisations. The third set of issues concerns the training and awareness of GIS available to current and potential GIS users within the organisations.

4.2.2.1 Implementation issues

Implementation issues covered as part of this study were mainly concerned with the role of GIS within the organisation. In all the organisations surveyed, GIS and spatial data collection and analysis occur as a separate unit within the organisation. There is often a clear distinction between spatial data, and other operational data within the organisation. This distinction extends to the operations of staff working with GIS data and software. These GIS units or sections are often occupied with stand-alone spatial data projects and operations, with little linkage to other operational data and procedures in other parts of the organisation. Examples of this situation were encountered in nearly all the organisations surveyed. This was traced to the fact that implementation of GIS was often perceived as an opportunity, rather than as a response to some recognised problem (Loulou 2001; Masikerei 2001). This has resulted in GIS being implemented as a separate section of the organisation, interacting with other sections of the organisation as and when needed.

In the case of the more successful GIS implementations such as the Department of Lands and Survey and TFL, the GIS has been located as an integral part of the operations of the organisation. In the Department of Lands and Survey, the inherent spatial nature of its operations has enabled GIS to become an almost ubiquitous tool within the organisation. The
use of GIS is still mostly confined to spatial data collection and maintenance, with little
analysis beyond statistical summaries and reports. The workflows within the organisation are
slowly integrating the various aspects of the GIS (in this case the FLIS) as part of their
normal operations. Examples of this include the CCMS, which is almost fully computerised
and integrated with the FLIS, and the topographic base. Both these digital products, while in
need of further enhancement, form the basis of the FLIS. There continue to be a number of
areas of the department's operations that have yet to be integrated with the FLIS, such as the
geodetic base, and the various attribute databases, which need to be linked to the various
spatial layers already stored (Williams 2001).

In the case of TFL, the GIS exists as a separate database administered by a separate GIS
team, but there are good linkages with other parts of the corporate database (Ravutia 2001).
Like the Department of Lands and Surveys, much of the spatial data has been captured and
linked to some fundamental asset management data, but further linkages with other aspects of
the corporate database (such as customer details) are need to fully realise the potential of the
GIS.

In the less successful implementations, the GIS tends to exist on the periphery of the
operations. The Department of Town and Country Planning, the Suva City Council and the
Bureau of Statistics all have small GIS operations, primarily concerned with map production.
The GIS within these organisations exists as a peripheral section with separate resources and
some data spatial data capture ability. The spatial data is primarily used for map production,
and is not usually linked to other databases within the organisation, limiting its potential uses.

The main reasons for the peripheral nature of GIS within these organisations (which could
potentially benefit greatly from GIS), is a lack of management support and awareness of the
potential uses of the technology. The technical staff interview expressed the view that
managers do not perceive, or are not aware of, the potential uses of GIS within the
organisation. The result is a lack of support for GIS, characterised by low priority for
funding and data development. The problem is further enhanced by the low level of
technology awareness and computer literacy (Williams 2001). The organisations have a
growing IT capability, but this tends to be focused on basic office automation tasks, and
financial management systems. Relatively new technologies such as GIS are not understood
in enough detail to warrant investment and development.
In the successful implementations at the Department of Lands and Survey and TFL, there has been a high level of management support and commitment to the technology. The FLIS is a comprehensive national level GIS, with virtually all parts of the department contributing to it. Its use has become an integral part of many operations in the department, and the management team of the department are committed to its development. The result of this is improved funding for upgrading technology, developing data, and improving staff skills through both internal and external training programmes. In TFL, the improved productivity in the asset management operations of the company have seen continued commitment to the technology from the company management.

4.2.2.2 Data distribution and exchange

One of the most contentious topics in recent years in GIS in Fiji has been that of data sharing and exchange. While a number of different organisations, primarily government departments, collect a wide variety of spatial and attribute data, the potential users of this data are varied and widespread and urban land data is no exception. In order for these potential users to utilise this spatial data, they must first acquire it from the appropriate agency or government department. It is this process of acquisition of data that has been particularly problematic.

To put these observations in to an appropriate context, a brief review of some of the issues and trends in data distribution is necessary. GIS data distribution has tended to follow one of two models. The first, and arguably more successful model, is based on US federal government legislation that requires all data collected under federal government programmes to be made available to the public at the cost of distribution (Clinton 1994). This has resulted in a vibrant and expanding GIS industry, based on the virtually free availability of federal framework data. An alternate model of data distribution is based on cost recovery and revenue generation. Under this model, data is sold to recover the cost of its collection, and provide income for the organisation, usually the national mapping agency. This model has been used in countries where state and statutory organisations are under pressure to attain some degree of financial independence (Campbell 1993).

The US model of freely available framework data is regarded as being more successful because it has been credited with helping create and sustain the multi-billion dollar industry
that GIS has become. From a financial perspective, this is justified because the income from
taxing these GIS-based activities has far exceeded the income that would have been
generated from selling the data on a cost-recovery basis. Many countries have recognised
this, and are starting to re-structure their data policies towards a more open and inclusive
distribution system.

In Fiji, there are few firm policies regarding data sharing and distribution. At the state level,
there is no official government policy on data, leaving individual departments to create ad
hoc policies as they see fit. With respect to spatial data, the FLISSC has formulated a data
distribution policy based on a cost-recovery system (Masikerei 2001). This policy charges
for data by file size, and has different rates for government, non-profit, and commercial
organisation. Other departments such as the Bureau of Statistics and the Department of
Town and Country Planning have no official policy regarding data sharing, with requests for
data being dealt with on a case by case basis.

The lack of clear policy guidelines regarding the distribution of data is the product of a
number of general factors, observed in the interview process. Firstly, there is virtually no
culture of data sharing within departments and organisations at the operational level. While
various inter-departmental and inter-organisational committees exist, these committees
function at the policy and management level, with little interaction taking place at the
operational level. This means that the exchange of 'nuts and bolts' data rarely takes place.
Secondly, the operational structures of most organisations are not designed for data exchange
to take place. Organisations are designed to collect and analyse data independently, with
little need for input from other organisations. Thirdly, the power of IT has meant that the
amount of digital data that can be distributed is almost limitless. This has presented a
challenge to organisations that have traditionally been able to service requests for individual
pieces of data; they are not sure if and how to respond to requests for large data sets.

4.2.2.3 Training and awareness

Formal GIS qualifications are only offered at the University of the South Pacific, in the form
of certificate and diploma programmes in GIS. There is also a degree programme offering
students majors in geography and information systems. These programmes attempt to
provide a broad based GIS education, rather than specific training. In the course of the
programme, students learn software spatial analysis skills, but are also exposed to concepts of
Geographic Information Science, and are encouraged to relate the GIS component of their programme to other disciplines such as geography, computer science and land management. While this programme exists primarily in an academic environment, it goes some way towards providing the software training skills required by organisations implementing GIS (Britton 2001).

One of the primary goals of the FLISSC is to disseminate and support the use of GIS and spatial data. To achieve this, the FLISSC runs an outreach programme to encourage the use of GIS and spatial data among government departments and agencies, statutory and non-governmental organisations, and the private sector (Masikerei 2001). This outreach programme takes the form of software training, and pilot project development for organisations and institutions that express an interest in GIS and the use of spatial data. Over the years, this programme has expanded the scope of GIS use in the country, with an increased awareness of the technology and its potential uses.

The South Pacific Applied Geoscience Commission (SOPAC) also provides a similar service, but usually on a consultancy basis, and provides this service to all its member countries in the Pacific region (Allinson 2001). Implementations of GIS in the Forestry Department and the Mineral Resources Department in Fiji are largely the product of SOPAC consultancy services.

The approach taken to training among the organisations surveyed is primarily of an opportunity type. Training programmes are offered when funds become available, rather than in response to a perceived need to develop a specific skill within the GIS implementation. The opportunity to undertake a training programme is usually viewed by the participant as an opportunity for promotion or transfer within the organisation, rather than contributing to the development of the GIS in the organisation (Williams 2001).

### 4.3 Results of test study to integrate urban spatial data

Following the organisational overview, and the identification of key aspects of GIS data and organisational processes that affect GIS implementation and development, a test study was carried out to assess the potential of creating an integrated urban GIS. The methodology for this test study has already been described in the methodology chapter, and presented here are the results of the test study.
4.3.1 Step 1 – to acquire data from five organisations and integrate this data into a single system.

The four organisations identified in the study were the FLISSC, the SCC, TFL and SOPAC. The area chosen for the study was central Suva. The acquisition of the data took place under informal arrangements with staff from each of the four organisations. The data acquired from each organisation is described as follows:

**Fiji Land Information System Support Centre:**
- a layer of property boundaries and a layer of property labels of central Suva, from the CCMS base in Microstation format
- the topographic base for central Suva, including contour lines in Microstation format

**Suva City Council:**
- the valuation index and land use zone for central Suva in digital spreadsheet format
- the large scale paper maps showing current zones for individual properties for central Suva

**Telecom Fiji Limited:**
- the network infrastructure for the central Suva area in Microstation format.

**South Pacific applied Geoscience Commission:**
- layer of points representing buildings, with associated attributes in MapInfo format.

Each data set acquired was considered to be the most current data available from each organisation. A potential problem with any kind of data integration project, and in particular a project dealing with dynamic urban data, is that the data may not always be from the same time period. This was the case with these data sets, but because of the lack of historical data, it was impossible to timestamp the data sets.

Two separate areas were selected for this part of the study. This first area was a section of central Suva, including part of the central business district containing office blocks, hotels and other administrative infrastructure. The second area was a residential area around the Vatuwaqa area. The two areas were chosen because between them they represented the

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4 SOPAC is a Pacific regional organisation providing geotechnical services to its various member countries. This includes providing GIS services and training, and the use of GIS in a variety of projects. One of the datasets collected by SOPAC is a comprehensive building survey of Suva.
majority of land use activity infrastructure found in the Suva area. They also represented areas that were covered to high level of completeness by the available data.

Figure 4-5. Location of study areas for data integration project.

4.3.2 Step 2 – integrating the data

The software environment chosen for this study was ArcView. The two main reasons for this were because of its relative simplicity to use (a straightforward, Windows-based desktop GIS), and its ability to geo-reference imagery and create 3D visualisations.

The integration section was the most technically challenging aspect of this pilot study. The first step was to polygonise the property boundaries for the study area. This was done in MapInfo format using a topology building plug-in to generate polygons from the parcel line boundaries. This proved to be relatively quick, as the parcel boundaries were accurately
mapped, with only minimal manual cleaning required to produce a consistent layer of polygons.

Once the polygons were created, the next stage was to link them to their property identification attributes from the layer of property labels. This was a fairly circuitous process, involving a number of steps. The label of each property is usually located within the boundary of the polygon. This label attribute was then geometrically linked to the parcel polygon itself, thus transferring the attribute from the centroid of the label, to the polygon. Using this method, approximately 85% of polygons could be identified, with unidentified polygons being manually identified from the label layer.

Once each polygon was logically identified with a lot and plan number, it was then possible to link this to the valuation index from the SCC database. This process revealed the greatest inconstancies in the data between the two organisations. The SCC valuation index is a subset of the national valuation index maintained by the Valuation Section of the Department of Lands and Surveys. In this index, each registered parcel is given a valuation number, and the property is described using various combinations of plan number, lot number, title number, lease number, and other miscellaneous descriptions. This is stored as a text string, with little internal consistency within the string. The result is that there is very low rate of success of directly matching the valuation index with the property polygons. For the sample areas that were generated, the majority of the valuation data had to be linked manually, by searching the text string for text from the polygon identifier. Also, each property was coded with a land use zone from the hard copy zone maps from the SCC.

The next step was to create a building layer on top of the property boundaries, by digitising from aerial photographs. A series of recent aerial photographs were scanned and rectified using coordinates from the parcel polygons. The general shape of the building footprint was manually digitised from the aerial photograph. Using the SOPAC layer of building points, each point was dragged on to its corresponding building polygon, and the attributes transferred to polygon.

The final step was to create the 3D models. The topographic data was used to generate 3D surfaces based on the contour lines. Then the various layers of data were draped over this and views from various angles generated to produce 3D visualisations.
4.3.3 Step 3 – Using the integrated data to produce visualisation models of the urban environment

Once the data layers had been created and attributes linked and verified, a variety of data views were produced, in the form of thematic maps and 3D views. This section describes a selection of these data views, and provides a summary of how they were created and possible uses for integrated urban management. The literature review documented a progression in GIS applications for urban data, beginning with simple plans views of urban boundaries, followed by linking properties with database attributes to produce thematic maps, through to complex 3D rendering of urban data. Examples of each of these forms of urban GIS are demonstrated below.

4.3.3.1 Plan views and multiple layers

With the basic parcel layer in polygon form, and linked to an accurate attribute database, simple visual search and identification is possible. Figure 4-6 shows the parcel layer of the study area, linked to its attribute database. Each parcel is separately identified, and searchable by lot and plan number, title and owner. This is the basic spatial layer to which many other attributes can be linked, and could be the basis for a wide variety of linked databases. The parcel base is often the fundamental spatial unit in many urban and even national scale GIS. There are approximately 10,000 parcels in the Suva area, which represents a data set that could easily be handled by a desktop GIS running on a modern PC, such as ArcView or MapInfo.
The use of rectified aerial photographs has already been discussed, and is shown in Figure 4-7. This view demonstrates how high-resolution imagery can be used as a reference guide for adding data, in this case, building footprints. ArcView’s Image Analyst was used to rectify the aerial photograph of the study area, and while not having the rectification capabilities of high-end image processing systems, it is still able to produce a reasonably accurate base from which the building footprint layer can be digitised.
These two views demonstrate the basic capabilities of integrating cadastral, imagery and infrastructure data. The cadastral layer provides a consistent spatial representation of land parcels, and with an appropriate parcel identification system, can be linked to a variety of external databases. The rectified aerial photograph provides a useful reference source for digitising infrastructure data such as building footprints.

**4.3.3.2 Thematic maps and enhanced data**

The ability to view and query attributes of individual parcels is a useful feature of any GIS, the ability to visualise large amounts of data in a spatial context is where the true power of GIS begins to be realised. Figure 4-8 shows a thematic view of the study area by land use zone. In this view, parcels are identified according to the zone, utilising the polygon structure of the parcel data. Without this polygon structure (as compared to the original line data), this kind of visualisation would not be possible.
In Figure 4-9, the building attributes are used to generate a thematic view, in this case, view by building construction. As in the previous example, each attribute in the layer can be used to generate a thematic view such as the ones shown here.
While neither of these two views reveal any immediately apparent spatial pattern, the fact that can be easily generated from the data sets demonstrates their utility as data visualisation tools.

4.3.3.3 3D views

The ability to view data in the vertical direction is achieved by utilising a vertical attribute. Two kinds of 3D views are shown here. The first is a familiar spatial representation of the physical data, incorporating the topography of the land with the approximate height of the buildings to generate a realistic view of the physical landscape. The second view maps the more abstract concept of property value (in this case normalised by area), to show relative property values. These visualisations are produced using the ArcView 3D Analyst extension.

Figure 4-10 is a 3D representation of the physical features of the area contained in the spatial data. In this case, two layers of vertical data are used, namely contours and buildings. The contour lines are projected into the vertical dimension using their height attribute, from which a TIN is generated. The rectified aerial photograph is then draped onto the TIN, and on top of this, the building layer is added. The buildings are projected into the vertical dimension with the height being calculated from the number of floors.

The second 3D view shows the property value normalised by area. This value is dynamically calculated from the property value and the area of each property, and converted to a cost per square meter. This value is then used as the vertical attribute, and a 3D view generated,
showing the area as a surface where height represents property values. This allows a viewer to visualise relative property prices for different land parcels.

Figure 4-11. 3D view of the study area showing relative property prices

The second study area was also used to generate similar views. This area was a more complex, denser urban structure. A similar data set was generated, this time covering a larger area, with greater diversity of land use and building construction type. Four layers were generated, namely topography, property boundaries, rectified air-photo and building footprints.
These layers were then used to generate a variety of 3D visualisations of the landscape, an example of which is shown in Figure 4-13.

Figure 4-13. 3D view of Study Area 2 showing buildings by main use, property boundaries, topography and air-photo all draped over a TIN generated surface.
Using ArcView's 3D Analyst tools, it is possible to rotate the image in 3 dimensions, and to adjust lighting and shading variables to produce a variety of visualisations. This is by far the most sophisticated modelling aspect of the study, and while it requires some time and effort to produce, it is not particularly difficult to do, providing the underlying data is properly structured.

This test study has provided a useful insight into the nature of urban spatial data in Suva. A number of important issues arise from this study, which will be discussed in detail in the following chapter. While the sample data sets used and the results produced are not meant to be complete working systems, they contribute to increasing the awareness of available data. The following chapter will build on this to attempt to outline a structure for a formalised, operational integrated urban GIS.
5 Discussion

The results of the study raise a number of important points, considered here for further discussion. To briefly review, the hypotheses of this study was formalised in the research methodology chapter in two parts as follows:

Firstly, “the process of GIS development in organisations in Fiji is a function of the efficiency of the existing information infrastructure and the level of awareness of, and support for, GIS within the organisation.”

Secondly, “the use of GIS for urban applications in Fiji can be enhanced through the use of a SDI-based method for data sharing.”

With respect to the first hypothesis, the results of the organisational survey, gained from the questionnaire survey and the focused interviews, suggest that information management efficiency, technology awareness and IT literacy all play a major part in the success of GIS implementation within the organisations surveyed. The more successful implementations were those where the GIS operations were made an important part of a managed information infrastructure. The FLIS and TFL GIS are both examples where the GIS has become an integral part of the organisation’s information infrastructure. Less successful GIS operations have tended to be those that exist on the periphery of the organisation. The levels of GIS awareness and overall IT literacy have also contributed significantly. Both organisations described previously as being more successful, have also had stronger IT capabilities, in both systems and human resources. This has enabled the adoption of new technology such as GIS to be less of a technical hurdle than for those organisations with limited IT capability.

It must also be stressed that time is also a significant factor in the success of the GIS operations surveyed. The FLIS and TFL have both been developing their GIS capabilities since the early 1990s. The other organisations (with the exception of the NLTB) have relatively younger GIS operations, many beginning in the late 1990s.

5.1 Characteristics of the GIS diffusion and implementation in Fiji

The results indicate that the process of diffusion of GIS in Fiji, in the organisations surveyed, has common characteristics with the diffusion process described in the literature. To review,
the diffusion process of any technology can be defined as; “an innovation, which is communicated through certain channel, over time, among members of a social system” (Rogers 1983). This process has been expressed in three forms, namely, technical determinism (in which the technology itself is the driving force behind the diffusion), managerial rationalism (in which the diffusion is based on a rational organisation strategy aimed at improved productivity) and social interactionism (where the diffusion process is a product of the social and organisational environment, and the relationships between them).

In this study of GIS in Fiji, aspects of all three forms of the diffusion process have been seen, with an emphasis on technology determinism and management rationalism. From the technical determinist point of view, the ‘newer is better’ ideology is pervasive across all the organisations. This is evidenced in the upgrading process of the GIS and IT environment of the organisations. When funds are available for upgrades, they are invariably spent on the latest available versions of hardware and software, with little or no advanced testing and cost-benefit analysis taking place. While some of this may be attributed to universal trends in the rapid changes of IT, the perception for the need for almost continuous upgrading tends to obscure some of the more fundamental challenges of IT management faced by the organisation. This was more common in the smaller organisations, which tended to have less structured IT infrastructure. IT hardware and software were acquired on an ad hoc basis, to fill perceived need in a particular section of the organisation, rather than as part of an overall IT strategic plan.

The managerial deterministic approach was also evident from discussion with staff at the management level. Many of them expressed a desire for a better, more managed GIS and IT infrastructure to help achieve medium and long term productivity goals. The main constraint to realising these goals was a breakdown between the management strategy and its technological implementation. In most cases, managers were aware of some of the uses and capabilities of GIS, and were able to express these as part of a management strategy. The realisation of this strategy through the deployment of a suitable technology (in this case GIS) was often more problematic. The relative complexity of the technology, and the lack of GIS specific training, lead to a breakdown between the managerial vision and its technical implementation.
The process of social interactionism plays a relatively small part in the documented adoption of GIS in organisations surveyed, but plays a vital role in the success of the GIS. As has been stated, much of the impetus for the adoption of GIS has been management led and technology driven, but often with little regard for the organisational environment in which it is to be used. This discordance between the vision and potential of the technology, and its role and function within the existing (or restructured) organisation infrastructure is a fundamental constraint to the success of the GIS.

5.2 Potential for integrating urban spatial data

The previous section in this chapter has described some of the characteristics of the GIS diffusion and implementation process observed in the organisations surveyed. These characteristics, together with the observations made during the case study part of this research, contribute to the following points of discussion on the potential for an integrated urban spatial data infrastructure. The first part of this discussion centres on the technical aspects of integrating urban spatial data, and is followed by the institutional aspects of realising such integration.

From a technical perspective, a number of fundamental issues need to be resolved. Firstly, the structure of the cadastral base needs to be addressed. In its current form, it is of little practical use beyond map production. The need for a consistent, current national cadastral base, linked to an attribute database of unique property identifiers is a basic pre-requisite for any kind of urban data integration project.

Secondly, a standardised parcel identification system needs to be developed and implemented. While the complexity of land administration in Fiji is acknowledged, the technical capabilities for developing a working land parcel identification system already exist. At the urban level, the parcel identification system needs to be supplemented by a street addressing system. Many GIS tools and algorithms have been developed to leverage data using street addressing systems, and to use these tools, urban areas need a functioning street addressing system.

In the discussion on SDI, a key dataset that was present in all the NSDI surveyed was the geodetic grid. The geodetic grid is the fundamental spatial framework on which all other spatial data is based. In the case of Fiji, the geodetic grid is missing from the national LIS,
and from any of the urban LIS surveyed. The geodetic grid is administered by the survey section of the Department of Lands and Surveys, and has yet to be integrated with the FLIS. This means that those wishing to develop survey grade spatial data are not able to do this from within the FLIS, but must do so from the separately administered geodetic network database. This has implications for high accuracy data, such as that used for utility networks, which require precise mapping so as to avoid damage to existing infrastructure.

Another technical aspect requiring consideration is that of data format. Most of the smaller organisations working with GIS use MapInfo, while the FLIS native data format is Intergraph Microstation. Translation between these formats can be problematic without a reasonable level of technical skill. This is especially in regard to translating data in the Fiji Map Grid (FMG) projection system, which requires some level of software customisation in order to be successful.

Finally, the actual process of physically transferring data can be problematic. All the organisations surveyed had some form of internal network capability, but moving data outside the network usually involved copying data on to a physical medium.

From an institutional perspective, a number of issues also arise requiring further discussion. Campbell and Masser (1995) highlight specific problem areas of variations in the priorities between participants, differences in the ability to exploit GIS facilities, differences in the level of awareness and spatial data handling skills and issues of agreements over access to information, leadership, data standards, equipment and training. All of these issues are seen to exist with regard to land information in the organisations surveyed.

Firstly, the lack of an inter-organisational steering committee to oversee the management and development of urban land information is an important factor. The DTCP is the organisation in charge of planning land development, and does so by acquiring data on a needs basis from other organisations. This data, together with consultation with other authorities and the public is used to plan land development on a variety of scales. This piecemeal approach to the use of land information means that organisations may not always feel part of the planning process, and thus structure and maintain their data in ways that are not compatible or useful to the planning process. This divergence of priorities results in divergence of data structures and standards, meaning that integrated urban management becomes a more complex process.
The wide differences in technical ability and awareness also contribute to difficulties in integrating urban land information. The larger organisations have a wider pool of technical expertise to draw on, and are able to leverage the technology more effectively. The higher level of management support and awareness of GIS technology also mean that it tends to function more efficiently in the larger organisations.

By far the most important inter-organisational factor concerns the agreements and procedures for the exchange of data. As has been outlined in the results of the organisational survey, the relative lack of effective data exchange is due to a lack of an information sharing culture and structure, and a general wariness of the ability of IT to make large amounts of data available for low cost and with relative ease.

For any integration project to be successful, effective and efficient data exchange is a fundamental pre-requisite. The various organisations surveyed all collect and maintain valuable data, primarily for use within the organisation. This focus on data for use within the organisation, while perfectly valid for the organisational needs and goals, tends to reduce its potential for use by other organisations that may have an interest in the data.

The main data exchange discussions have focused on the use of FLIS data. As has been outlined in the results, the FLIS makes data available to a variety of categories of users on a cost recovery basis. This system includes other government departments, leading to a situation where one arm of the government is required to pay another for the use of its data. This has led to various arms of government (and other users and creators of spatial data) seeing each other as customers and providers, rather than possible collaborators. Each organisation continues to create and use data for the day-to-day operations of the organisation, and sees this data also as a commodity that could raise revenue, while at the same time being discouraged in acquiring data from other organisations because of the costs. This culture of viewing data as a commodity is a primary factor inhibiting the exchange of data between the organisations.

The point concerning the lack of an urban management umbrella organisation also contributes to the problems of data exchange. As has been discussed, at the national level, the FLIC oversees the operations of the FLIS, and works to coordinate LIS projects,
operations and policies. While the success of the FLIC in carrying out its mandate is debatable, it does provide an overriding structure under which national level LIS can be structured. No such similar organisation exists at the urban or individual municipal level. This is not to say that collaborative projects do not take place. As the organisational survey shows, a measure of ad hoc data exchange does occur, but it is aimed at the satisfying the current operational needs of the organisation, rather than contributing to an integrated urban management system.

A further issue that arose from the organisational surveyed with regard to data exchange, concerned the ability of IT to make large volumes of data available for the same amount of effort as small volumes. It was observed that while there was a general willingness to make individual pieces of data available (such as the attributes of a single parcel, or the plans of a small number of parcels within a single plan sheet), the concept of making a large chunk of this data available was viewed with suspicion. In these cases, the data was already in digital form, and the difference between collecting a single piece of data and the entire data set was simply a difference in file size, and negligible in terms of time and human resource costs. With this data already being in the public domain, so the speak, it should, theoretically, not have made any difference whether a single piece of data was released or the entire data set.

A number of reasons can be attributed to this, one of which is the view of data as a potential commodity. This has already been discussed, but is worth mentioning again in this context. With data being viewed as a potential commodity, the more data that was released, the higher its perceived value would be. With the nebulous state of data exchange agreements, and the many ad hoc practices that take place, it is difficult to quantify the real and perceived value of such data.

A further contributing factor to this reluctance to release large volumes of data may have been to a perception that releasing a copy of the data would result in loss of control of the data. While the original data set within the organisation would remain the only 'true' version of the data, having copies of the data circulating might enable the data to be used to generate information that might be contrary to the decisions and policies of the originating organisation. The public scrutiny of government decisions and policies is an integral part of a functioning democracy, and while it may be applauded in theory, the reality in practice may be a reluctance to be scrutinised and potentially criticised. Hence the institutional reticence
towards the release of data that may be used to critically examine the decisions and policies of the organisation. Obviously this was never alluded to in the organisational survey, but the inability to provide specific reasons why large volumes of data would not be released to the public, may point to a perception held, but not expressed, that this would lead to loss of control and open decision and policy challenges.

This discussion on the characteristics of integrating urban spatial data has outlined some of the technical and institutional issues surround the possibilities for such an integration to take place. While many of the technical shortcomings of the data can be remedied through technical solutions (as demonstrated in the case study) it is the institutional issues that present the greatest challenges towards integrating urban spatial data. The literature review outlined the concept of SDI, and it is this concept that will be used as a template for integrating urban spatial data.

5.3 A proposed urban Spatial Data Infrastructure

As has been outlined in the literature review, SDI is composed of four components, namely, the institutional framework, technical standards, fundamental or core datasets, and data clearinghouse information, including metadata. This section will propose a SDI for urban data integration, taking in to consideration the results of the study from both technical and institutional perspectives.

Briefly described, the institutional framework covers not only the organisational and human resources, but also the business context and policy relating to the use, dissemination, cost and copyright of data. Technical standards are crucial to the linkage, exchange and integration of data, particularly as the SDI data model is based on a distributed approach to data management and ownership. The fundamental or core datasets are the tangible parts of the infrastructure, the framework or foundation onto which other data can be added. The final component, the data clearinghouse, is the discovery, access and delivery mechanism for third party data sets that are available for wider use.

5.3.1 Institutional framework

Firstly, and most importantly, is the institutional framework. As has been discussed, while there is a national spatial data organisation, there is no such organisation at the municipal level. One of the first steps in establishing an SDI would be to establish an umbrella council
to oversee the operations of spatial data integration within the municipal region. This council
would be made up of organisations working with and using spatial data in the municipal area.
Obvious inclusions in the council would be all the organisations surveyed in this study,
together with emergency response authorities (police, fire and medical services) and
consumer and business organisations. Such a council would need to define goals and
structure for an integrated urban SDI, together with policies for the use, dissemination, cost
and ownership of the data to be included in the SDI.

5.3.2 Technical standards

The technical standards required for an urban SDI would need to address some of the issues
raised in the results of the data integration project. The most important issue would be the
adoption and accepted use of a standardised parcel identification system. This would enable
the linkage of existing parcel data maintained by the various organisations. Under the current
practice, there is no standardised method of identifying a parcel of land, with organisation
adopting their internal identification method. At present, the only linkage possible is through
a largely manual process of searching for title, lease or plan and lot number, none of which
are standardised.

A second major technical issue that would need to be addressed would be the spatial
representation of various data sets. While the definition of these data sets is described in the
next section, a number of technical issues such as spatial structure (e.g. parcels as polygons
rather than joined lines) would need to be explicitly defined. Spatially accuracy and margins
of error would also need to be explicitly defined. This is important in the high density urban
environment, where various infrastructure networks share relatively small spaces, and the
accurate mapping is essential to avoid disruptions.

A third technical issue would be adoption of the FMG as the standard projection system for
spatial data. This has been adopted by the larger organisations that have the necessary
technical skills to customise their software to handle data in the FMG, but less technically
capable organisations would need guidance on setting up their data capture in FMG and
converting existing data to FMG. This is the kind of role that the umbrella organisation can
assist in, by making the expertise of the larger organisations available to others.
5.3.3 Fundamental data sets

Based on the concepts of SDI, these would involve the definition and use of fundamental and framework data sets. Fundamental data sets are the foundation on which other information is constructed and includes a base to which users can add or attach geographic items and attributes or a reference source for accurately registering and compiling the participant's own data sets.

The primary fundamental data sets that would be necessary for an integrated urban GIS would be the geodetic control network. All survey data is based on this network, and for organisations carrying out high accuracy surveys (such as those used by utility networks described above), the geodetic control network is of fundamental importance in creating and combining wide area surveys. Also, the cadastral mapping system is based on the geodetic control network, and any changes to the cadastral base are made with reference to this network.

The cadastral network could also be considered a fundamental data set. Organisations that would participate in an urban GIS would maintain large amounts of data referenced by some form of property identification, such as street address, title or lease number, or plan and lot number. Under the present spatial data available, this data cannot be effectively visualised because of the poor links with property identification methods, and the non-polygon structure of the cadastral data. In order for the cadastral base to become an effective fundamental data set, it must first be fully polygonised with parcels identified under the standard structure proposed previously.

Other layers of data that could considered to be fundamental to such an integrated urban system would be detailed road data (such as road surfaces, traffic markings and sidewalks), and high accuracy utility data. Standards would need to be agreed between utilities and road maintenance and construction organisations on the level of accuracy required, especially in regard to buried infrastructure. With good surveying techniques, and differential GPS, accuracies in the range of centimetres are readily attainable.
High resolution ortho-rectified aerial photography and satellite imagery would also contribute significantly to the SDI. Since many land features can be seen on an ortho-image, it can serve as a backdrop for visual reference purposes.

5.3.4 Data clearinghouse and metadata

The final component, the data clearinghouse, is the discovery, access and delivery mechanism for third party data sets that are available for wider use. A variety of methods exist for creating such a clearinghouse. A commonly used low technology approach is the publication, and periodic update, of a printed or on-line data catalogue. This is usually in the form of a series of metadata documents, outlining the structure of the data available, and the method for acquiring it. Such a method would be suited for the Suva situation, because of the relatively low penetration of internet technologies into spatial data organisations.

Internet technologies offer a more sophisticated and efficient mechanism for building and maintaining data clearinghouses and metadata. Generally, a central website contains the data catalogue, with links to the individual data sets available on other web and file servers housed in the various organisations that create and maintain the individual data sets. The central data catalogue is usually searchable (especially for larger data sets), various spatial and attribute criteria.

The advantage of such an online system is obvious; immediate access to current data sets. In order to create such a system, a number of technical prerequisites are necessary. Firstly, internet technologies must be come part of the IT infrastructure of the organisations. All the organisations surveyed had some level of internal network capability, which was utilised primarily for file transfer. With this infrastructure in place, it is not a particularly difficult task to set up local intranets to begin using web based tools for maintaining control of data. Once intranets are established and used within the organisation to control data, the next step would be to connect the intranet to the web via the local ISP. Most government departments and have internet connectivity through the government IT provider (Caine 2001), while other organisations would need to invest in web connectivity through the local ISP. Internet access in Fiji is still relatively expensive, and an alternative would be to join the government run Wide Area Network (WAN) covering central Suva. All the organisations have their headquarters and GIS operations in central Suva, and it would not be unfeasible for them to physically connect to the government WAN, which at present links a number of government
offices in central Suva. Obviously there would need to be various levels of political and policy considerations, but the fact remains that the technology is already in place to create such networks. Also, most of the organisations surveyed are government departments, many of which are already connected to the government WAN. These organisations could begin the process using the existing infrastructure, and other could join in due course once access agreements are in place.

This chapter has discussed some of the main issues raised from the results of the study. Institutional and technical issues are both considered in the context of creating an integrated urban GIS. This is proposed using the SDI model for data management and is presented in the context of the local GIS environment.
6 Conclusion

This study has attempted to evaluate the potential for using geo-spatial tools for integrating various aspects of urban management through the integration, management and visualisation of spatial data. The increasingly complex and dynamic nature of urban areas requires suitable tools for improving the management and planning of these areas. In the Pacific, urban areas are growing at unprecedented rates, and in many cases poorly planned resulting in a variety of resource, economic and social problems. Suva is no exception, and as one of the largest urban areas in the Pacific region, many of the problems of rapid urbanisation with poor control and management are evident.

The choice of Suva as the study area was based not only on its urban characteristics, but also for the fact that it has a growing GIS capability. This capability is reaching the stage in its development where enough data has been collected in a variety of contexts to start building large scale GIS applications. Various government departments, utilities and statutory authorities have significant amounts of digital, geo-spatial data, which currently functions to fulfil the immediate data needs of the organisations. This data could also possibly be integrated and used as part of a larger-scale, inter-organisational urban management and planning tool. It is this potential that this study aims to investigate.

6.1 Overview of study

The first part of this study was a literature review covering four main topics. Firstly, the nature of urbanisation was reviewed, leading to an overview of the urbanisation process of the greater Suva area. Secondly, the current use of GIS tools and techniques in the urban context was studied. GIS has been used in a number of ways, from basic data management, to complex visualisation and urban planning. Thirdly, the diffusion and implementation process of GIS was considered. Although GIS is primarily a technology, research shows that the institutional and social context in which it operates contribute to a large degree to the success of its operation. This concept constitutes the first hypothesis of the study, which seeks to determine the effect of an organisational structure on the success of its GIS operations. Finally, the concept of Spatial Data Infrastructure was reviewed. SDI is a spatial data management tool designed for the management, distribution and discovery of spatial data at the national level. However, this structure can also be used for data management at a variety of levels, and it is this structure that is proposed as a method for creating an integrated
urban GIS for Suva. This concept constitutes the second hypothesis of the study, which suggests that using SDI-based data integration can enhance the use of urban applications of GIS.

The methodology of this study was primarily qualitative. GIS and IT in general are established tools used in quantitative analysis, and study aimed to evaluate some of the qualitative factors influencing the use of such a tool. To achieve this, a number of organisations in Suva using GIS and working in urban management-related areas were surveyed. This survey aimed to determine the role and function of GIS within the organisation, and to evaluate the various factors influencing its level and type of use. Following that, a test study was carried out, in which spatial data from a number of organisations was acquired, and integrated to determine the potential for a more large-scale data integration application for urban management. Using the data, a number of sample data integration and visualisation products were produced. The process of carrying out this integration and producing the visualisations was documented, and contributed to the proposed urban SDI.

The discussion chapter covered the points raised in the organisation survey and data integration study, with the aim of proposing an urban SDI, suitable for the local context. The discussion covered both the technical challenges, presented by limitations in the data, and the institutional challenges, particularly, the structure of data distribution across a range of organisations.

6.2 Concluding comments

This study has revealed a number of interesting aspects of the state of GIS development in Fiji, in general terms, with some specific points for urban applications.

The amount of spatial data and the number of organisations working with GIS in Fiji is growing rapidly. In common with the majority of GIS projects, the initial phase in all these organisations has been concerned with data collection, in some cases on a large scale. The data collection, storage and management has been the primary activity up to now, but more recently, attention has started to turn towards high level data analysis and integration. The completion of data capture for the FLIS has greatly enhanced the potential for more sophisticated use of GIS beyond simple mapping and data management.
Also, the critical mass of organisations with the capability to use GIS, and with a level of awareness regarding the potential uses of GIS and spatial data has been reached. In the context of urban applications of GIS, the situation is the same. What this study has shown is that, while the potential exists, as demonstrated through the case study, the reality as that technical shortcomings in the available data, and the lack of established structures for data distribution are limiting the potential uses of this valuable data.

The technical shortcomings of the data ascertained from the study stem from a variety of causes. Prime among these is the early concern with data collection and management for map and cartographic production. Much of the spatial data capture has been carried out without much regard for established spatial data structures and topological consistency. This lack of structure resulted in difficulty in linking with other data sets and attribute databases, and while being useable for cartographic production, has failed to stimulate significantly much further analysis. In the urban setting, the lack of a standard land parcel identification system has contributed to the problem of connecting to external data sources.

From an institutional perspective, the relative success and efficiency of the GIS operations in the organisations tended to relate to the position of the GIS within the organisation’s structure. In the more successful operations, the GIS was positioned as an integral part of the overall information infrastructure of the organisation, and was tightly integrated in to its operations. These also tended to be the larger organisations, which were also able to provide higher levels of IT support. The less successful GIS operations were observed to be on the periphery of the information and decision making structure of the organisation, and were also limited in terms of IT capability and support.

The technical limitations of the data were relatively easily addressed in the sample data sets that were used. These data sets were obviously a small subset of the entire data covering the greater Suva area, but the process of cleaning, structuring and attributing the data, while tedious, is not technically sophisticated and can be achieved for large volumes of data given sufficient time. What are less easily addressed are the more tenuous institutional issues surrounding the distribution of data required to create integrated GIS. This study has suggested the concept of a municipal scale SDI as a possible approach to this issue. The high density of data and the dynamic nature of the urban environment are situations suited to GIS-
based data management, and what is need is a structure to bring this data together. SDI is a possible approach to this problem, that has proven success at the national level in a growing number of countries, and has the potential for success in a wider variety of contexts such as the one suggested here.

A number of areas for future research suggest themselves from the results of this study. Obvious amongst these is a critical evaluation of the role of SDI in facilitating urban spatial data distribution and use, should such a system be developed. It seems inevitable that some form of more structured data distribution system will evolve in the future, and a critical examination of such a system may prove be an interesting and productive exercise. Another area of possible research would be the impact of internet technologies on the distribution of spatial data. The potential for use of internet technologies has been discussed, but because of its relatively low penetration in local data management and government services, its use is still small. Over time, the necessary infrastructure will be come more readily accessible, and the impact this would have on data distribution, both internally and externally would make for an interesting study.
Bibliography


DTCP (1998). Lami town planning scheme statement. Suva, Department of Town and Country Planning.


Narayan, J. (2001). Reserach Officer, DTCP.


